# A STUDY OF THE COMPUTER MANUFACTURING INDUSTRY IN THE UNITED STATES

by

Thomas Hadley Billings

# United States
# Naval Postgraduate School

# THESIS

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by

Thomas Hadley Billings
and
Richard Claude Hogan

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Thomas Hadley Billings
Lieutenant Commander, Supply Corps, United States Navy
B.S., United States Naval Academy, 1959

and

Richard Claude Hogan
Lieutenant Commander, Supply Corps, United States Navy
B.A., University of Mississippi, 1958
M.A., Roosevelt University of Chicago, 1962

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## ABSTRACT

A study of the origins and evolution of the computer manufacturing industry in the United States, with emphasis on the economic importance of its present structure and conduct. The examination of supply and demand as determinants of the market mechanism is presented in a classic outline of current economic form for the market structure, conduct and performance of basic industries. The analysis of demand utilizes the first published government material on the computer industry. Derivation of Lorenz curves for this new industry and its concentration represent the first so produced. The synthesis of the manufacturers' performance is developed from the structure and conduct. That performance is separately examined in reference to public policy, with emphasis on current legal actions and antitrust suits.

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# I. INTRODUCTION

The computer industry has been described as the major growth industry of the 20th century. Economists predict that by the year 2000, more persons will be employed in the data processing and related industries than in any other single business. The computer industry has drastically affected the entire fabric of our society, and has significantly influenced many other segments of American industry, ranging from publishing to insurance, transportation to retail trade.

The census takers reveal that in a brief span of twenty years, the world wide total of U. S. computers has reached 90,000 systems, valued at $30 billion. One dramatic illustration of the industry's growth is the rapid tempo of change in associated technology. Calculations in Charles Babbage's 19th century analytical engine, involving the acceleration, rotation and stopping of a cog-wheel, were performed on the order of about one per second. Relays, utilizing a spring-loaded switch, could be opened or closed in a millisecond. Vacuum tubes, with no moveable parts at all, decreased this time unit another thousandfold. Today, semiconductor electronics make use of components which can change state in a nanosecond (i.e., one thousandth of a millionth of a second).[1]

The purpose of this study is to examine an industry which is currently in its early stages of growth. The origins and

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[1] Nievergelt, J., "Computers and Computing - Past, Present, Future," IEEE Spectrum, January 1968, p. 58.

evolution of the industry will be presented, with emphasis on its present structure and conduct. Additionally, the effects of public policy and government regulation on this "young industry" will be analyzed. Finally, this case study adds one more industry to the works of other authors covering the organization of American industry.

Following this introduction, the thesis is organized into three sections. The first section begins with a history emphasizing the chronological relationships in the development of the industry, examines the size and composition of the industry, and looks briefly at the international operations. Sections III and IV examine the two major forces which mold the architecture and character of the industry - market mechanism and government regulation. Responding to the influence of a competitive market, the natural interaction of supply and demand tends to formulate the structure of an industry, govern its conduct, and establish the prices. When the market process goes astray, public justice demands that the government intervene to control and regulate the industry in keeping with federal antitrust policy.

The computer industry today consists of several distinct sectors - computer manufacturers, component manufacturers, service bureaus, time-sharing vendors, used computer brokers, computer leasing companies, and software firms.[2] Each of these sectors rightfully plays a significant role in the overall industry, and while none has escaped the attention

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[2]Sharpe, W. F., The Economics of Computers, Columbia University Press, 1969, p. 183.

of this study, the primary focus has been placed on the computer manufacturing portion of the industry. One further qualification is necessary. Although the production of special purpose and analog computers, such as airbourne and radar system computers, constitutes a significant part of the business of computer manufacturers, this study will concern itself solely with general-purpose digital computers.

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# II. THE EVOLUTION

## A. HISTORY

This section of the study will hopefully provide some insight into the origins of the computer industry and its growth and development into the giant of the American economy. An attempt is made to look into several aspects of its development such as early data processing methods, the birth of new concepts, the breakthrough in technology, the people involved, the laboratory work at universities and colleges, the early partnerships and companies, the mergers and formation of trusts, and the migration of scientists and technology from one operation or company to another.

While compiling the history of the computer industry, the authors discovered frequent inconsistencies among the various sources of information with respect to the exact dates of particular occurrences. The most reliable data, in the authors' judgement, have been used in the main body of the paper. For the interested reader, the inconsistent information, where occurring, has been included in footnotes.

### 1. Data Processing - The Beginnings

The computer industry is a new industry only in the sense that it involves a radical advance in technology. Realistically, the electronic computer merely represents the most recent improvement in the field of data processing (i.e., the recording and manipulation of data), which had its beginning in pre-historic days.

Recording techniques began with the earliest businessman making scratches on rocks, notches on trees and marks on mud walls. Improvements through the years led to the development of the first commercial typewriter, the Remington No. 1, in September 1873. The oldest surviving written records are pictographic writings on clay tablets made by the ancient Sumerians, predecessors of the Babalonians, during the period 3700 to 3000 B.S.[3]

Computing devices had their beginning when primitive man became aware of his inherent means of counting in the form of his fingers and toes. Later, he learned to use pebbles or grains of corn as counting devices. In about 3000 B.C., in the Tigres-Euphrates Valley, someone designed a clay board with grooves into which pebbles were placed, and counting was performed by moving the pebbles from one side to the other. The clay board was the predecessor to the abacus, which was invented in China about 2600 B.C.[4]

Punched card machines had their origin in the 18th century with the perforated-paper-operated weaving loom design by Basil Bouchon in 1725, and a similar design by M. Falcon in 1728. The first successful loom application was achieved by Joseph Marie Jacquard, in 1801, using a punched card design he conceived in 1745.[5]

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[3] Arnold, R. R., Hill, H. C., and Nichols, A. V., Introduction to Data Processing, John Wiley and Sons, 1966, p. 15-16.

[4] Ibid., p. 20-21.

[5] Ibid., p. 25.

The computer is merely a single machine (ultimately, a system of machines) that performs the data processing operations of several machines. The computer was not invented, it evolved. It was "perceived as a possibility, and its function imagined, but had to await the discovery and development of new materials, miniaturization, the control of power, new languages, a trained community of specialists, and the application of a good deal of money".[6]

A general purpose computer was first conceived in principle in the 19th century, when Charles Babbage designed his analytical engine. Babbage failed to influence history merely because the only implementation of his design possible at that time was mechanical, and a mechanical device of the complexity of a computer was all but impossible to build and maintain.[7]

The principles conceived by Babbage were ultimately realized in the world's first digital computer, the Mark I, which was dedicated on August 7, 1944, and put into operation in a basement at Harvard University in Cambridge, Massachusetts.[8] The fifteen years that followed saw the digital computer transformed from the use of relays and rotating switches to vacuum tubes and transformers, from electro-mechanical, delay-line, and cathode-ray-tube storage to magnetic drum, tape, and core storage, from input/output speeds of one to two dozen characters

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[6]Rodgers, W. H., <u>Think - A Biography of the Watsons and IBM</u>, Stein and Day, 1969, p. 165.

[7]Nievergelt, p. 58

[8]Rodgers, p. 177.

per second to speeds of tens of thousands of characters per second, from computation speeds of a few operations per second to tens of thousands of operations per second.[9]

The era of electronic computers was initiated in 1946 by the University of Pennsylvania's ENIAC, built by Professors Eckert and Mauchly for the U. S. Army.

2. The Generations

The period of development of the electronic computer is generally divided into generations. However, the methods of division and the resulting time periods of the generations are the subject of some disagreement. Some say that the length of each cycle is two times the length of the previous cycle because of the mysterious "principle of binary powers".[10] Others separate the generations in terms of software (i.e., programming languages) or operation system developments. Perhaps the most common approach is based on the evolution of hardware (i.e., machine components) technology as follows: 1st generation - vacuum tubes, 2nd generation - transistors, 3rd generation - integrated circuits, 4th generation - batch fabrication or large scale integration.[11] A final analysis of computer generations, called the cycle theory, tends to

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[9] Serrell, R., and others, "The Evolution of Computing Machines and Systems," Proceedings of the IRE, May 1962, p. 1055-1056.

[10] Amdahl, G. M. and Amdahl, L. D., "Fourth-generation Hardware," Datamation, January 1967, p. 25-26.

[11] Ibid.

to incorporate features of the other three methods. According to this theory, significant economic and technical transistions occur in the industry every five years, resulting in the appearance of a new generation and the beginning of a new cycle.[12]

The first generation is generally accepted to be the period from 1954 (first commercial installation of UNIVAC and IBM 650) to 1959, and is characterized by vacuum tubes, slow speeds, and limited memory capacity. The computer lines of different manufacturers were isolated, unrelated, and designed primarily for scientific application.[13]

The second generation is considered to extend from 1959 to 1964, and experienced the introduction of solid state components (i.e., transistors) on a large scale, and increased speed and memory capacity. Manufacturers distinguished between their business and scientific oriented computers.[14]

The third generation, 1965 and later, gave birth to microelectronic circuits, faster main memory, greater memory size, more flexible mass random-access memories, extensive data communications equipment, various remote terminal devices, and improved programming languages.[15]

Differences of opinion exist regarding the emergence of the fourth generation. Only two years ago, authors wrote

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[12] McGovern, P. J., "The Computer Field and the IBM 360," Computers and Automation, January 1967, p. 16-17.

[13] Ibid.

[14] Ibid.

[15] Ibid.

of "informed sources" declaring that the third generation of computers would have a life span of ten years as contrasted with the previous generations of only five years each.[16] More recent authors believe that the industry has quietly stepped into the fourth generation in 1970. Changes were judged to be subtle rather than profound, and consist of differences of degree rather than kind. Those anticipating a markedly distinctive breakthrough in technology will have missed the beginning of this evolutionary vice revolutionary generation.[17] Accordingly, with the announcement by IBM of the System 370 in April of this year, some accepted the increased speed and memory capacity as the fourth generation, others were surprised by its premature arrival, and others disappointedly asked, "Is that all there is?" Only in the retrospect of future years, will one be able to judge more accurately if 1970 marked the beginning of the fourth generation.

3. <u>The Chronology</u>

<u>1642</u>

The first adding machine, a stylus operated mechanical device capable of performing addition and subtraction, was designed and built by Blaise Pascal, age nineteen.[18]

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[16] Computer Yearbook and Directory : 1968, American Data Processing Inc., p. 739.

[17] Bradburn, J. R., "Where is the Computer Industry Heading?" Computers and Automation, January 1970, p. 11.

[18] Arnold, p. 22.

1671

The concept of a calculating machine, the first device that would multiply by repeated additions, was proposed by Gottfried Liebnitz.[19]

1673

Liebnitz' calculating machine was completed, but it never proved to be completely reliable.[20]

1725

Basil Bouchon designed a weaving loom operated by perforated paper.[21]

1728

M. Falcon designed a weaving loom, similar to Bouchon's, operated by perforated cards.[22]

1745

A third design of a weaving loom was developed by Frenchman, Joseph Marie Jacquard. Jacquard's design involved a method for using holes in cards to control the selection of different colored threads in weaving designs.[23]

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[19] Ibid.; and Serrell, p. 1041.

[20] Bowden, B. V., ed., Faster Than Thought, Sir Isaac Pitman and Sons, 1953, p. 6.

[21] Arnold, p. 25.

[22] Ibid.

[23] Davis, G. B., An Introduction to Electronic Computers, McGraw-Hill, 1965, p. 6.

1801

A textile loom operated by punched cards was built using the Jacquard design of 1745. This loom represented the first successful application of the principles demonstrated by Jacquard, Bouchon and Falcon.[24]

1811

Charles Babbage, a student at Trinity College in Cambridge, conceived the design of an entirely mechanical device, called the Difference Engine, to make calculations for logarithmic and trigonometric tables.[25]

1820

The Arithmometer was designed and built by Charles X. Thomas. It was the first machine capable of performing the four basic arithmetic functions well enough for commerical manufacture, but only a few were ever constructed.[26]

1822

Babbage completed the construction of a small working model of his Difference Engine. Referred to by others as "Babbage's folly," it utilized several of the principles of Jacquard's punched cards.[27] Babbage, true to his character, immediately proposed building the largest Difference Engine that ever might be needed. In the following year, he received

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[24] Serrell, p. 1041; and Arnold, p. 25.

[25] Moseley, M., Irascible Genius, A Life of Charles Babbage Inventor, Hutchinson of London, 1964, p. 49.

[26] Serrell, p. 104.

[27] Arnold, p. 25

some limited financial backing for his Engine from the Royal Society, and began work.[28]

1833

Babbage was encountering overwhelming difficulty in the construction of his Difference Engine. His government financing was coming to an end, and engineering technology was simply not equal to the task of building a device as complicated and precise as he had perceived.[29]

Undaunted, Babbage conceived the design of the Analytical Engine, for which he requested but was refused government support.[30] He proceeded to work on this new machine, using his own money, until his death in 1871. Thousands of detailed drawings were produced, but only a few parts were ever completed.[31]

Babbage's design of the Analytical Engine's stored program was remarkably similar in concept to a modern computer.[32] Ultimately, the Engine was to include all the elements of a modern, general purpose, digital computer. The design called for a memory of a thousand words of fifty digits each held in counting wheels; control by Jacquard cards; branching by skipping forward or backward a prescribed number of cards; and random access to function tables, which were

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[28]Serrell, p. 1042; and Moseley, p. 73.

[29]Serrell, p. 1042.

[30]Moseley, p. 135-139.

[31]Ibid., p. 152, 253.

[32]Davis, p. 4.

stored on cards separately, by ringing a bell and displaying the number of the card deck that the operator should load.[33]

1873

The first commercial typewriter, the Remington No. 1, was developed by Christopher Sholes, and manufactured by E. Remington and Sons.[34]

1884

A key-set, adding printing machine was designed by William S. Burroughs.[35]

1887

A modern machine-readable punched card and related card-processing equipment were designed by Herman Hollerith, an employee with the Bureau of Census. The cards used 45 columns (later expanded to 80 columns) of rectangular holes. The machines were used in the 1890 census to record, compile and tabulate census data. Cards would be individually positioned over mercury-filled cups. Rows of pins descended onto the card surface, through the holes into the mercury, and closed circuits which advanced the dials one position. Fifty to seventy cards were processed per minute.[36]

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[33] Serrell, p. 1042.

[34] Arnold, p. 19; and Sperry Rand Corporation, A History of Sperry Rand Corporation, 1967, p. 3. Hereafter cited as "Sperry".

[35] Arnold, p. 23.

[36] Ibid., p. 25-26; and Davis, p. 6.

1890

The Rand Ledger Company was organized by James Rand Sr.[37]

1896

Hollerith left the Census Bureau to manufacture and market his machines and cards. He formed the Tabulating Machine Company.[38]

1908

James Powers, another employee with the Bureau of Census, designed some punched cards and card processing machinery with slightly different features. Powers' cards used 90 columns of round holes. His equipment was used in the 1910 census.[39]

1910

Sperry Gyroscope Company was organized by Elmer Ambrose Sperry, inventor.[40]

1911

The Monroe Calculator was introduced by Jay R. Monroe. The manufacturer used a design originating with Frank S. Baldwin.[41]

James Powers left the Census Bureau and established the Powers Accounting Machine Company.[42]

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[37] Sperry, p. 4

[38] Davis, p. 6.

[39] Ibid.

[40] Sperry, p. 12.

[41] Arnold, p. 4.

[42] Ibid., p. 26.

The Computing-Tabulating-Recording (CTR) Company was organized by Charles R. Flint. The company resulted from a merger of three companies (originally 13 companies) including the Tabulating Machine Company of Herman Hollerith. The founder, Charles Flint, was a munitions trader, organizer of trusts, key figure in development of U. S. Rubber, gun runner, and double agent in Latin American revolutions.[43]

<u>1913</u>

E. Remington and Sons became Remington Typewriter Company.[44]

Thomas J. Watson, Sales Manager of National Cash Register Company was fired. He and thirty other members of the "Cash" had been convicted for restraint of trade and maintaining a monopoly - the results of their overzealous pursuit of competitors.[45]

<u>1914</u>

Thomas Watson was hired by Charles Flint as the General Manager of the C-T-R Company.[46]

<u>1915</u>

Watson was elevated to President of the C-T-R Company, following the appeals court set-aside of the antitrust convictions. Among other actions, he immediately set up a

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[43] <u>Ibid.</u>, p. 27; and Rodgers, p. 67-69.

[44] <u>Sperry</u>, p. 4.

[45] Belden, T. G. and Belden, R. M., <u>The Lengthening Shadow - The Life of Thomas J. Watson</u>, Brown Little and Company, 1961, p. 86; and Rodgers, p. 54-65.

[46] Rodgers, p. 69-70.

product research department to improve the Hollerith machine to compete with the technologically superior Powers Company product.[47]

American Kardex Company was organized by James Rand Jr.[48]

1917

The C-T-R Company entered the Canadian market under the name of International Business Machines Company, Ltd.[49]

1919

The C-T-R Company had moved far into the lead in the tabulating machine business.[50]

1924

The C-T-R Company adopted the name of International Business Machines. Watson expressed his concept that the entire world was the true territory of their international company and its machines designed to serve business.[51]

1925

A large scale analog computer was built by Dr. Vannevar Bush and his associates at Massachusetts Institute of Technology. Although it was an electrically powered

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[47] Ibid., p. 76, 79.

[48] Sperry, p. 4.

[49] International Business Machines, Highlights of IBM History, 1970, p. 2. Hereafter cited as "IBM."

[50] Rodgers, p. 79.

[51] Ibid., p. 83; and Arnold, p. 27; and IBM, p. 3.

mechanical operation of limited accuracy, it marked the beginning of the modern era of mechanical computation.[52]

The Rand Ledger and the American Kardex Companies merged to become the Rand Kardex Company.[53]

1927

The Remington Typewriter and Rand Kardex Companies merged to become Remington Rand, Inc.[54]

Remington Rand, Inc. acquired the Powers Accounting Machine Company.[55]

1933

The Sperry Gyroscope Company merged with several other companies and became the Sperry Corporation.[56]

1935

Dr. Bush and his associates at M.I.T. began the development of a second, improved model of their analog computer.[57]

During these years, Thomas Watson was active in various organizations and public affairs. He enjoyed a particularly close association with Dr. Butler, the President of Columbia University, and was ultimately made a trustee of the University.

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[52] Bernstein, J., The Analytical Engine, Computers - Past, Present, and Future, Random House, 1963, p. 50.

[53] Sperry, p. 4.

[54] Ibid.

[55] Arnold, p. 26.

[56] Sperry, p. 11-12.

[57] Bernstein, p. 50.

He made gifts of several tabulating machines to Dr. Wood at Columbia. Due to the foresight of Dr. Wallace Eckert, who was able to envision revolutionary uses for the machines being used by Dr. Wood, the equipment was applied to the study of astronomy and used to make lunar calculations. Eckert proceeded to establish the Thomas J. Watson Astronomical Computing Bureau, the second IBM operation at Columbia, using a modified 601 multiplier. Many scientists were drawn to the laboratories of Wood and Eckert at Columbia, and among them was Dr. Howard Aiken, "who was to open other gates to the computer age."[58]

## 1939

Howard Aiken and his associates at Harvard, working in conjunction with IBM engineers, began development of the Automatic Sequence Controlled Calculator (Mark I). The Mark I was the first machine to exploit the principles of the analytical engine conceived by Babbage, and the first attempt to combine various operations into a single device. It was the immediate predecessor of the automatic electronic computer.[59]

## World War II

Dr. Wallace Eckert and IBM machines were used to speed up the air assault on German submarines in the Atlantic. Action against submarines had been experiencing delays in signaling

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[58]Rodgers, p. 140-143.

[59]Sharpe, p. 185; and Arnold, p. 28; and Davis, p. 6, 9.

for help while obtaining a navigational fix. The manual calculations required after the sextant readings were entirely too slow. Dr. Eckert was ordered to the Naval Observatory, Washington, where he calculated, from the available tables whose accuracy had been confirmed by IBM equipment at Columbia, nautical almanacs for air and sea navigation. These printed calculations, the first scientific computer output in the world, enabled loss of life and tonnage in the North Atlantic to be diminished within a matter of weeks.[60]

1942

The second model of Bush's analog computer was completed, but the completion was kept secret until the end of the war, since it was used extensively in the computation of artillery firing tables.[61]

1943

Dr. J. Presper Eckert (no relation to Wallace Eckert at Columbia) and Dr. John Mauchly and their co-workers at the Moore School of Electrical Engineering at the University of Pennsylvania began building the ENIAC (Electronic Numerical Integrator and Computer).[62] The U. S. Army Ballistics Research Laboratory at Aberdeen, Maryland, with the help of the Moore School, had been using Dr. Bush's 1942 model analog

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[60] Rodgers, p. 143-144.

[61] Bernstein, p. 50.

[62] Rosen, S., "Electronic Computers: A Historical Survey," Computing Surveys, March 1969, p. 7-8.

computer, supplemented by a hundred or more girls doing manual calculations, to produce artillery firing tables. A young Army lieutenant, Herman H. Goldstein, had been sent to Philadelphia to recruit more girls, where he happened to read a report written by Eckert and Mauchly in the previous year describing a revolutionary computer design. Recognizing the value of a computer in solving the firing tables problem and possibly shortening the war, he persuaded his Army bosses to provide financial support, and the building of the ENIAC began.[63]

Dr. John von Neumann served as consultant on the design and building of the ENIAC - the first attempt to build an all-electronic computer utilizing very high speed vacuum-tube switching devices.[64]

1944

The Mark I was completed, and put into operation in the basement of Harvard's Cruft Laboratory in Cambridge, Massachusetts. It was dedicated on August seventh, and formally named the IBM Automatic Sequence Controlled Calculator. A huge electromechanical machine, 51 feet long and eight feet high, it used standard IBM business machine parts, and was controlled by punched paper tape.[65] Although the use of vacuum tubes in ENIAC made the Mark I obsolete, Babbage's

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[63]Rodgers, p. 175-176.

[64]Ibid.

[65]Serrell, p. 1043; and Arnold, p. 28.

dream of 1833 had finally been fulfilled. The designer, Howard Aiken, commented, "If Babbage had lived seventy-five years later, I would have been out of a job."[67]

1945

Dr. John von Neumann develcped the draft proposal for the EDVAC (Electronic Discrete Variable Automatic Computer). Von Neumann's work represented the first published concept of a stored-program, general-purpose computer, and called for the use of acoustic delay lines with mercury as the transmission medium. Since von Neumann's writings contained descriptions of much of the logic being developed by Eckert and Mauchly at the University of Pennsylvania, many persons believe that all three deserve credit as co-inventors of the stored-program, digital computer as we know it today.[68]

1946

The ENIAC was completed. The world's first all-electronic computer went into operation for the U. S. Army at Aberdeen, Maryland, on February 15. (It was turned off for the last time on October 2, 1955.) The ENIAC was unquestionably the most complicated electronic device in the world. Its successful functioning depended on the simultaneous operation of 18,000 vacuum tubes. Stories were told that during its construction, the lights in West Philadelphia

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[67] Bernstein, p. 52; and Rodgers, p. 177.

[68] Rosen, p. 8-9; and Bernstein, p. 60-63.

would dim whenever it was turned on.[69] The behemoth weighed almost thirty tons, and required 1500 square feet of floor space.[70] Its weaknesses were the limited storage and the lack of a stored program. Thirty minutes to a full day were required to do its set-up, and it had to be re-wired or read-into as work progressed.[71]

Almost immediately upon completion of the ENIAC, Professors Eckert and Mauchly began work on the EDVAC - von Neumann's proposal of the previous year. The EDVAC was the first stored-program computer to be started, a prototype of serial computers, and the basis for the latter SEAC (1948) and EDSAC (1949).[72]

Von Neumann, in the meantime, with the help of his associates at the Institute for Advanced Studies (I.A.S.) in Princeton, New Jersey, began the development of the IAS Computer.[73]

IBM began the development of the IBM 604 Electronic Calculator, a general purpose digital computer.[74]

Later in the year, Eckert and Mauchly left the University of Pennsylvania to form their own computer manufacturing partnership. They began work on the BINAC, a small

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[69] Rosen, p. 8.

[70] Serrell, p. 1045.

[71] Arnold, p. 29; and Rodgers, p. 175-176.

[72] Sharpe, p. 186; and Davis, p. 9.

[73] Rosen, p. 9.

[74] Serrell, p. 1045.

binary computer, and the UNIVAC (Universal Automatic Computer) under a contract from the National Bureau of Standards.[75]

1947

Engineering Research Associates (E.R.A) was organized by Captain Howard T. Engstrom and Lieutenant Commander William Norris. The nucleus of this young company consisted of a group of Navy engineers, who had been actively engaged during the war on communications research which led them into computer technology. From that year until 1953, there were only three major sources of computer expertise in the U. S., the E.R.A., the Eckert-Mauchly group, and the scientists at the M.I.T. laboratory.[76]

Professor Maurice Wilkes, at Cambridge University in England, began building the EDSAC (Electronic Delay Storage Automatic Calculator).[77] Professor Wilkes had spent the previous summer with the Eckert-Mauchly group at the University of Pennsylvania.[78]

Under sponsorship of the Office of Naval Research and the U. S. Air Force, the Servomechanisms Laboratory at M.I.T. began development of the Whirlwind I.[79] A major contribution of the Whirlwind project was an extensive set of detailed

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[75] Sharpe, p. 186.

[76] Wise, T. A., "Control Data's Magnificent Fumble," Fortune, April 1966, p. 166. Hereafter cited as "Fumble".

[77] Sharpe, p. 186, gives the name as the "Electronic Discrete Automatic Computer."

[78] Rosen, p. 9.

[79] Serrell, p. 1047.

logic diagrams, which though never published were widely circulated and helped to educate early workers.[80]

Eckert and Mauchly incorporated their partnership to become the Eckert and Mauchly Computer Corporation.[81]

1948

IBM announced the completion of the Selective Sequence Electronic Calculator. Although an improvement over the Mark I, the machine was only partially electronic, containing 13,000 vacuum tubes and 23,000 electro-mechanical relays.[82] Thomas Watson considered the computer as merely a showcase for IBM engineering talent and a gift to the field of science, but saw no commercial application.[83] The machine was put into operation at IBM's New York headquarters.[84]

Raytheon Corporation's Dr. Richard Bloch, previously the director of the Mark I project, began development of the RAYDAC for the National Bureau of Standards. Slow production resulted in contract cancellation. One RAYDAC was ultimately installed in 1952 at Point Mugu, California.[85]

As a result of the cancelled contract with Raytheon, the Electronic Computer Laboratory of the National Bureau of

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[80]Rosen, p. 9.

[81]Serrell, p. 1048.

[82]Rosen, p. 12; and IBM, p. 5.

[83]Sharpe, p. 187.

[84]Serrell, p. 1045.

[85]Rosen, p. 15; and Pantages, Angeline, "Computings Early Years," Datamation, October 1967, p. 62. Hereafter cited as "Early Years."

Standards began building the SEAC (Standards' Eastern Automatic Computer).[86]

The Bell Laboratories completed the development of the transistor. Its later use (commercially in 1959) marked the beginning of the second generation.[87]

IBM commenced delivery of the IBM 604 Electronic Calculating Punch. A descendent of the IBM 603 Punched Card Multiplier, the 604 contained over 1400 tubes, making electronic speeds available in punched card handling systems.[88] The 604 was often referred to as the Electronic Calculator. Over 4000 of these machines were ultimately produced.[89]

IBM began the development of the CPC (Card Programmed Calculator). The CPC descended from the connection, made for Northrup Aviation, of an IBM 601 Multiplier (later a 603 Electronic Multiplier) to an IBM 405 Alphabetic Accounting Machine.[90]

1949

The Eckert and Mauchly Computer Corporation completed development of the BINAC. The BINAC was the first computer with complete internal self-checking, but unfortunately it never performed satisfactorily.[91]

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86 Rosen, p. 10; and Serrell, p. 1046.

87 Davis, p. 11.

88 Rosen, p. 12.

89 Serrell, p. 1045.

90 Schussel, G., "IBM vs. REMRAND," Datamation, May and June 1965, p. 57; and Serrell, p. 1045. However, contrast Rosen, p. 12, who gives credit for the original concept to Northrup in that the connection of equipment was made by Northrup personnel and involved the IBM 604 Calculating Punch vice the 601 or the 603.

91 Arnold, p.29.

Eckert and Mauchly visited the Watson Laboratory seeking a contract of financial support to put the UNIVAC on the market. Thomas Watson, believing that the greatest market potential for computers was in scientific rather than business applications, gave them the "brush off," indicating that "no reasonable interaction was possible."[92]

Professor Wilkes at Cambridge completed construction of the EDSAC, the first stored program computer to be completed. The EDVAC was the first stored program computer to be started, but its progress was slowed considerably by the departure of Eckert and Mauchly from the University of Pennsylvania.[93]

IBM began the development of the IBM 650, an intermediate size, vacuum-tube computer which became the workhorse of the industry during the late 1950's.[94]

1950

James Rand Jr. invited Eckert and Mauchly to Florida to be wined and dined both ashore and aboard his yacht. Rand acquired the corporation, operated it as the Eckert and Mauchly Division of Remington Rand Inc., and financed the continued development of UNIVAC.[95]

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[92]Rodgers, p. 199; and "A Survey and Study of the Computer Field," Computers and Automation, January 1963, p. 23. Hereafter cited as "A Survey."

[93]Rosen, p. 9.

[94]Serrell, p. 1050.

[95]Sharpe, p. 186; and Rodgers, p. 199; and Sperry, p. 8. However, contrast Arnold, p. 30; and Davis, p. 10; who both list the acquisition date as 1949.

The National Bureau of Standards completed their SEAC and SWAC (Standards' Eastern, and Western, Automatic Computer). SEAC was the first stored program computer to be operated in the U. S. Originally, mercury delay lines, and later, other memory systems were utilized.[96]

The EDVAC was completed at the Aberdeen Proving Ground, Maryland.[97]

IBM began the development of the IBM 701 Data Processing System, originally called the Defense Calculator.[98]

The Korean War brought about a great expansion in the computer industry. During this period, the industry was essentially non-commercial, and was supported by universities and the government. It is possible that without the government (and particularly the military) backing, there would be no computer industry today.[99]

<u>1951</u>

The Whirlwind I was completed and put into operation in March. This was the first attempt to use the computer in a command and control operation.[100] The Whirlwind memory consisted of electrostatic tubes developed at M.I.T., a variation of the Williams cathode-ray-tube developed at the University of Manchester.[101]

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[96] Rosen, p. 10.

[97] Bernstein, p. 63. Contrast with Sharpe, p. 186, who gives the completion date as 1952.

[98] Rosen, p. 13; and Serrell, p. 1050.

[99] Rosen, p. 13; and Sharpe, p. 186.

[100] Pantages, <u>Early Years</u>, p. 65.

[101] Sharpe, p. 186; and Serrell, p. 1047.

The first UNIVAC went into operation in April at the Census Bureau, and became a household word due to its role in tabulating and forecasting election returns. Five other machines were soon delivered to other government agencies. The television publicity of the UNIVAC accomplishments shook Thomas Watson and caused tremors throughout IBM. One of the IBM men involved at that time commented that the news "... frightened the pee out of the old man, who was convinced he had lost his grip."[102]

1952

Remington Rand acquired the Engineering Research Associates, and established it as a separate division operating in parallel with the Eckert and Mauchly Division. E.R.A. had already developed the ERA 1101, the first computer to use a magnetic drum memory.[103]

The Computer Research Corporation introduced the CRC 102.[104]

The IAS Computer, designed by von Neumann, and financed by the U. S. Army Ordnance Corps, was completed at the Institute for Advanced Studies.[105] The machine utilized cathode-ray-tube storage and performed parallel binary

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[102] Rodgers, p. 199.

[103] Sharpe, p. 186-187.

[104] *Ibid.*, p. 187.

[105] Serrell, p. 1049.

arithmetic. Several others of the same design have since been built, including ORDVAC and ILLIAC at the University of Illinois, the MANIAC at Los Alamos, the WEIZAC at the Weizman Institute in Israel, and one version built at the Rand Corporation affectionately called the JOHNNIAC (over von Neumann's objections).[106]

The Whirlwind I was converted to magnetic core memory. It was the first computer to successfully incorporate the coincident-current magnetic core.[107]

IBM's first production computer, the IBM 701 Data Processing System was completed.[108] The 701 utilized the Williams' tube memory, magnetic drum with tape backup, random access, and parallel binary arithmetic.[109]

<u>1953</u>

The Electro-Data Corporation, originally the computer division of Consolidated Engineering Corporation of Pasadena, built the Datatron computer.[110]

The Computer Research Corporation built the CADAC. National Cash Register later acquired Computer Research, and marketed its CADAC 102A and CADAC 102D.[111]

IBM announced the IBM 702 - a business computer designed to compete with UNIVAC.[112]

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[106] Rosen, p. 9.

[107] Sharpe, p. 186.

[108] Rosen, p. 13; and Sharpe, p. 187; give the completion date as 1953.

[109] Serrell, p. 1050; and <u>IBM</u>, p. 5.

[110] Rosen, p. 18.

[111] <u>Ibid</u>.

[112] Rosen, p. 13; and "A Survey," p. 23.

## 1954

The UNIVAC was delivered to the General Electric Appliance Park in Louisville, Kentucky, the first commercial application of a stored program computer.[113]

The first IBM 650 was installed. Ultimately, over 1000 of these systems were sold by IBM.[114]

The IBM 702 was determined to be inadequate in several respects and generally inferior to the UNIVAC. The company announced the IBM 705 as its replacement and withdrew the 702 from the market, although a few were delivered in the following year.[115]

## 1955

Raytheon and Honeywell set up a firm to manufacture the Datamatic 1000, a large scale machine. The new firm was controlled 60% by Honeywell, 40% by Raytheon.[116]

The Eckert and Mauchly Division and the E.R.A. Division were combined into the UNIVAC Division of Remington Rand Incorporated. The UNIVAC became the UNIVAC I, and the ERA 1103 became the UNIVAC Scientific Computer. Later, in June, Remington Rand merged with the Sperry Corporation to become Sperry Rand Corporation. The UNIVAC II, with magnetic core memory was announced.[117]

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[113] Davis, p. 10.

[114] Sharpe, p. 187.

[115] Rosen, p. 13.

[116] Sharpe, p. 190. Contrast with Rosen, p. 16, who gives the date of the merger as 1954.

[117] Rosen, p. 12.

IBM began delivery of the IBM 705, a character-oriented commercial data-processing computer utilizing a magnetic-core memory. Many orders were received from UNIVAC customers as UNIVAC II delivery was delayed. While many argued that the 705 was still inferior to the UNIVAC I, IBM moved into the lead in the industry.[118]

1956

IBM announced the building of the STRETCH computer under contract from Los Alamos Research Laboratory. The STRETCH was known later as the IBM 7030.[119]

IBM introduced its IBM 704, which was originally conceived as a modification to the 701 incorporating the magnetic core (IBM 701M), but ended up sufficiently different to warrant redesignation. The 704 was an outstanding machine for this period, and created a near monopoly for IBM in large scale scientific computers. It featured a high speed magnetic core, floating point arithmetic, and indexing operations.[120] Its only competitor in this field was the Sperry Rand 1103 series (originally the ERA 1103, then the UNIVAC Scientific), which incorporated a magnetic core in the 1103A, added floating point hardware in the 1103AF, and was the first computer with an interrupt system. Although it was considered by many to be

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[118] *Ibid.*, p. 13.

[119] *Ibid.*, p. 26.

[120] Serrell, p. 1052.

superior to the 704, late delivery and poor support led to loss of sales.[121]

Burroughs purchased Electro-Data Corporation with its Datatron computer which proved to be excellent competition to the IBM 650.[122] Burroughs produced Electro-Data's small scale machines, the E101 and E103. These machines were so small that a British scientist, Dr. Wormsley, while visiting the Burroughs Research Center, commented about a mountain that had labored to produce a mouse.[123]

By mid-year, IBM, the leading computer manufacturer despite UNIVAC's early lead, had delivered 76 large machines with orders for 193 more, while the UNIVAC division's figures were 46 and 65 respectively.[124]

Sperry Rand's UNIVAC Division contracted to build the LARC (Livermore Automic Research Computer) for the Livermore Research Laboratory of the A.E.C.[125]

RCA delivered the BISMAC, which though already outmoded, proved to be an "interesting failure." It utilized a small magnetic core backed by a magnetic drum, and as the cost of magnetic cores was reduced, drum computers became obsolete. The interesting feature of the BISMAC was the tape system designed to completely eliminate mounting and dismounting of tapes. Several hundred tapes permanently occupied

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[121] Rosen, p. 14.
[122] "A Survey," p. 23.
[123] Rosen, p. 19-20.
[124] Schussel, p. 55.
[125] Rosen, p. 26.

their own low cost tape transports which were interconnected through a relay switching center.[126]

1957

The Control Data Corporation was established by "dropouts" from the UNIVAC organization. The departing group was headed by William Norris, now president and chairman, and Seymour R. Cray, considered the leading computer developer in the world. In almost no time at all, they had a computer designed, ready for marketing, and their first order received (from the Naval Postgraduate School at Monterey).[127]

Equipment difficulty and financial problems forced the Underwood Corporation to withdraw from the field.[128]

Honeywell bought out Raytheon's interest (40%) in the Datamatic 1000, and operated the organization as a separate division. Deliveries were too late and the cost too great, however, to overtake the IBM 705. The computer was withdrawn from the market.[129]

Philco began production of the Philco 2000.[130]

1958

The first IBM 709 was delivered. It featured an advanced, internally buffered input/output system, but its use of vacuum tubes made it already obsolete.[131]

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[126] Ibid., p. 16-17.

[127] Ibid., p. 23; and Wareham, H. B., IBM: Management as a Molder of Corporate Success, Masters Thesis, George Washington University, 1964, p. 24, 26.

[128] Rosen, p. 18.

[129] Ibid., p. 16.

[130] Ibid., p. 22.

[131] Ibid., p. 15.

The first installation of the Burroughs 220 was made in December.[132]

1959

The second generation of computers began. The transistor effort got underway with the NCR 304, a joint NCR/GE effort which proved to be too slow; the RCA 501, also slow but with a COBOL compiler; the IBM 7070; the IBM 7080, built to run the IBM 705 programs; the CDC 1604; the Honeywell 800; and Burroughs' B5000 and B5500. Transistors also made possible the rush to relatively small computers such as the IBM 1400 and IBM 1600, which were marketed by the thousands; the RCA 301 and CDC 160 which sold hundreds; the Burroughs 200 series; the Honeywell 400 series; the GE 200 series; the NCR 300 series; and several others.[133]

The IBM 705 was recognized as the standard in the large scale data processing field, but its use of vacuum tubes made it extremely vunerable to competition.[134]

Control Data announced the CDC 1604, its second generation entry, in October.[135]

National Cash Register delivered its new generation computer, the NCR 304, in November.[136]

Dr. John Mauchly left Sperry Rand to set up Mauchly Associates, a computer service company.[137]

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[132] Serrell, p. 1052.

[133] Rosen, p. 21-22.

[134] Ibid., p. 14.

[135] Wise, "Fumble," p. 165.

[136] Serrell, p. 1052.

[137] "Dr. John Mauchly, Un-Success Story," Forbes, 15 June 1968, p. 55.

A UNIVAC Scientific Computer, the 1105, replaced the UNIVAC I at the Census Bureau. This machine featured buffered input/output, but just as with the IBM 709, its vacuum tubes made it obsolete. It was used, however, in the census of 1960.[138]

The first two IBM 7090's, solid state systems, were delivered in November to the Ballistic Missile Early Warning System. The 7090's were an extremely successful computer. Hundreds of systems were sold at $3 million per copy. The machine was later converted to the slightly faster IBM 7094.[139]

RCA made the first installation of its second generation computer, the RCA 501, in December.[140]

<u>1960</u>

The UNIVAC LARC was installed at Livermore. Another was built and installed at the Navy's David Taylor Model Basin at Carderock, Maryland, near Washington, D. C. These computers were classified as market failures, but did provide significant stimulus to the industry from 1956 to 1959.[141]

The Philco 2000 was delivered, but even prior to delivery, it had been overtaken technologically by the IBM 7090.[142]

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[138] Rosen, p. 15.

[139] *Ibid.*, p. 24.

[140] Serrell, p. 1053.

[141] Rosen, p. 26-27.

[142] *Ibid.*, p. 23.

The first installation of the UNIVAC Solid State 80/90, a medium-sized data processing system, was made in January. As evidence of the IBM influence in the market, this UNIVAC's card equipment could be adapted to handle 80 or 90 column cards.[143]

Control Data delivered and installed its first CDC 1604 in January.[144]

After a three year development period, IBM installed its relatively small sized computer, the IBM 1401, in September.[145] The 1401 proved to be IMB's most popular computer. More than 10,000 were ultimately installed.[146]

The first delivery of the Honeywell 800 was made in December. The 800 was a general purpose system capable of running eight distinct programs simultaneously without special instructions.[147]

Control Data began building the CDC 6600, a super computer for the Livermore Laboratory of the A.E.C. The specifications called for a computer three times as powerful as the STRETCH computer which IBM was building for the Los Alamos laboratory.[148] Although CDC had received the contract and commenced construction, the 6600 was not publically announced until 1963.

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[143] Serrell, p. 1053-1054.

[144] Ibid., p. 1054.

[145] Ibid.

[146] Wise, T. A., "IBM's $5,000,000,000 Gamble," Fortune, September 1966, p. 122. Hereafter cited as "Gamble."

[147] Serrell, p. 1054.

[148] Rosen, p. 27.

Dr. Daniel Slotnick, who was receiving almost no financial support at Westinghouse for his work on a computer called the SOLOMON, transferred his efforts to the University of Illinois. With financial support from ARPA (Advanced Research Projects Agency) of the Department of Defense, he began the development of a computer, similar in concept to the SOLOMCN, called the ILLIAC IV. The ILLIAC employed a highly controversial parallel processor approach.[149]

Sperry Rand introduced the UNIVAC III, but it was too expensive for the medium priced field.[150]

1961

The Bendix G-20 was delivered and installed at the Humble Research Center, Houston, Texas. The G-20 contained tubes as well as diodes and transistors, and was used for cil reserve studies involving solutions of problems requiring eight to ten billion arithmetic operations.[151]

IBM began the design of its System 360 with the ultimate goal of complete standardization and compatibility within IBM of all codes, modes, and units. Preliminary design and engineering of the 360 were conducted under tight security. Public announcement of the new system was withheld until 1964.[152]

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[149] Ibid., p. 28-29.

[150] Rosen, p. 25.

[151] Serrell, p. 1055.

[152] Rosen, p. 29.

IBM's STRETCH computer was delivered to Los Alamos, but failed to perform at advertised speeds. It was so disappointingly slow, that it was classified a failure, and in the face of orders for 15 STRETCH systems, IBM withdrew it from the market.[153]

Control Data's president, William Norris, expressed concern that STRETCH was not so much a failure as it was a staged maneuver to curtail CDC's entry into the scientific computer market by robbing it of potential customers.[154] This accusation by Norris was somewhat surprising in view of the announcement dates of the respective systems. IBM had announced its STRETCH computer in 1956, far in advance of CDC's building of a scientific computer for the A.E.C., which began in 1960.

1962

The UNIVAC 1107 was introduced as the successor to the 1103 series. Although it featured the thin film memory, it was marketed too much later than competitive scientific computers.[155]

Control Data introduced its CDC 3600 in May.[156]

IBM introduced the IBM 7040 and IBM 7044 computers, which were similar to the IBM 7090 but offered somewhat less

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[153] Ibid., p. 26-27.

[154] Rodgers, p. 258.

[155] Rosen, p. 25.

[156] Wise, "Fumble," p. 165.

performance at a greatly reduced price. It also marketed a direct-coupled system in which the 7094 executed jobs which were staged and buffered in the 7040.[157]

<u>1963</u>

Philco delivered its Philco 2000, Model 212, perhaps the most powerful computer then being delivered. Philco was later absorbed by merger into the Ford Motor Company, after which Ford decided against any major investment in the computer industry.[158]

Control Data Corporation acquired the computer division of Bendix Corporation, with the rights and maintenance responsibility for its G-15 and G-20 computers. Later it delivered the first CDC 3600, and was then considered a major factor in the large scale computer market.[159] In August, Control Data announced its next super-computer, the CDC 6600.[160]

The Census Bureau's UNIVAC I was retired to the Smithsonian Institute after 73,000 hours of operational use. It has since been replaced at the Bureau by two UNIVAC 1107's and a UNIVAC 1108.[161]

In December, Honeywell announced the Honeywell 200, ultimately a very successful computer expanded into a whole line from the small 100 to the very large 1200.[162] The 200

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[157] Rosen, p. 24.
[158] *Ibid.*, p. 23.
[159] Sharpe, p. 189.
[160] Wise, "Fumble," p. 165.
[161] *Sperry*, p. 7.
[162] Rosen, p. 31.

was designed along the same lines as the IBM 1401, yet was 30% cheaper. Its announcement prompted a speed-up in the IBM 360 development.[163] Honeywell was then IBM's closest competitor in the business data processing field.[164]

1964

Manufacturers began to speak in terms of the third generation of computers with their new product lines making use of monolithic integrated circuitry; such as the GE 600 series, as a successor to the IBM 7090; Burroughs' full line up to the very large 6500, 7500, and 8500; the UNIVAÇ 9000 series; CDC's medium priced 3000 series; NCR's Century Systems; and smaller companies such as Digital Equipment Corporation with its PDP series, and Scientific Data Systems with its Sigma series.[165]

In April, IBM announced its System 360, a third generation system responding to the challenge of being out-maneuvered in scientific advances. IBM spent over $5 billion to develop, redesign, program, and systematize the full line of 360 computers, a compatible, multi-model system. Initially, six models of the 360 were announced, the Models 30, 40, 50, 60, 62, and 70. Later, to ensure coverage of all classes of users, Models 65 and 75 were introduced, replacing the 60, 62,

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[163] Wise, T. A., "The Rocky Road to the Marketplace," Fortune, October 1966, p. 201. Hereafter cited as "Rocky."

[164] Rosen, p. 31.

[165] Ibid.

and 70. Although it failed to meet April 1965 delivery dates, the Corporation shipped more than 15,000 installations in the next three years at an average cost of $300 thousand.[166]

Raytheon purchased the computer division of Packard-Bell with the Models 250 and 440 computers.[167]

General Electric acquired controlling rights to Compagnie des Machines Bull of France.[168] That summer, it announced that the 600 series of computers would feature time sharing capabilities.[169]

Control Data delivered the CDC 660 to the Livermore Lab of the A.E.C. The 6600 was even faster than had been prescribed in the specifications, and utilized multiple arithmetic and logic units with ten peripheral processors. By the following year, every A.E.C. installation had a 6600 either installed or on order.[170]

Project MAC at M.I.T. ordered a dual processor GE 645 computer. MAC had been working on time sharing concepts for several years using IBM equipment. Following the lead of MAC, Bell Telephone Laboratory announced an order for four GE 645's. The time-sharing bandwagon was forming with a rush to G.E., and IBM's reaction was violent.[171] It immediately

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[166] Ibid., p. 30; and Rodgers, p. 275.

[167] Sharpe, p. 189-190.

[168] Ibid., p. 190.

[169] Wise, "Rocky," p. 206.

[170] Rosen, p. 27.

[171] Ibid., p. 32.

announced a large time sharing machine, the Model 67 to the System 360.[172]

RCA announced its Spectra 70 computer, a series compatible with the IBM 360. Its models were numbered 35, 45, and 55 to indicate performance bracketing 360 Models 30, 40, 50, and 60, at lower prices. The Spectra 70 represented a move toward standardization in the industry.[173]

Control Data announced the CDC 6800, a computer logically identical to the CDC 6600, but four times as fast and no more expensive.[174]

IBM announced additional models of the System 360 to meet the challenge of the competition. The Model 90 was a super-computer designed to counter the CDC 6800. The Model 44 was destined for specific scientific uses. The Model 20 represented a move into the lower end of the market.[175]

1965

The Model 67 of IBM's System 360 appeared to be the most promising answer to large scale time sharing, and the company launched a major effort to develop the necessary operating system (TSS). Prospective users were planning installations with hundreds of consoles simultaneously on-line.[176]

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[172] Wise, "Rocky," p. 206.

[173] Rosen, p. 30.

[174] Ibid., p. 28.

[175] Wise, "Rocky," p. 206.

[176] Rosen, p. 33.

The UNIVAC 1108 was introduced, featuring integrated circuitry.

General Electric acquired the computer division of Olivetti in Italy.[177]

Raytheon purchased BIAX memory business of Philco's Aeronutronics Division.[178]

1966

By mid-year, it became apparent that IBM's TSS performance would be marginal at best. It would be difficult to support even a few consoles. Most orders for the Model 67 were withdrawn. The few systems that were delivered provided limited service to about eight consoles.[179]

Honeywell acquired the Computer Control Company with its DDP series of computers.[180]

1967

IBM discontinued production of the series 90 of its System 360. Only the twenty systems already on order were ultimately delivered.[181]

Xerox Data Systems (XDS) was formed in May by the Xerox acquisition of Scientific Data Systems (SDS).[182]

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[177] Sharpe, p. 190.

[178] Ibid.

[179] Rosen, p. 33.

[180] Sharpe, p. 190.

[181] Rosen, p. 28.

[182] "Office Equipment - Basic Analysis," Standard and Poor's Industry Surveys, 9 July 1970, p. 011. Hereafter cited as "Basic Analysis."

IBM announced the model 85 of the System 360, a very large scale computer with better price and performance characteristics than its series 90.[183]

Efforts continued to develop improved time-sharing software for the 360-67, but by June it appeared that even with the best possible operating system, the 67 would not achieve a satisfactory level of time-sharing performance.[184]

1968

Control Data withdrew the CDC 6800 from the market, and announced a new, more powerful computer, the CDC 7600.[185]

1969

IBM announced the System 3, not really a mini-computer but aimed roughly at the same market.[186] The System 3 utilized a new smaller sized punched card, IBM's first departure from its standard 80 column card. Also announced was a new model of the System 360, the Model 195, IBM's most powerful computer.[187]

1970

IBM announced its new computer, the Series 370, with the initial models, 155 and 165. Although arriving somewhat sooner than had been anticipated, it was considered by many as the beginning of the fourth generation. The new models demonstrated faster performance with greater memory and programming

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[183] Rosen, p. 28.

[184] Ibid., p. 33.

[185] Ibid., p. 28.

[186] Elliott, J. R. Jr., "Thinking Hard," Barrons, 2 November 1970, p. 8.

[187] IBM, p. 17.

capacity, but were a disappointment to those expecting any break-through in state-of-the-art technology. The system was called "evolutionary" not revolutionary.[188]

RCA responded to the announcement with an improved Spectra 70 system, and Burroughs' answer was a modification to the B-500 line called the B-700's.[189]

Honeywell, Inc. acquired the bulk of General Electric's computer business in May, and established Honeywell Information Systems, Inc. to be operated as a subsidiary. Honeywell will initially own 81.5% and G.E. will retain 18.5% of the new company.[190]

In September, IBM announced an additional model of the System 370, the Model 145. The 145 was the first general-purpose computer with internal monolithic memory, utilizing integrated circuit chips instead of separately wired ferrite cores.[191]

B. SIZE AND COMPOSITION

Understandably, information on computer installations and orders is extremely difficult to obtain. Manufacturers almost unanimously refuse to release these statistics. International Business Machines (IBM), quite naturally, is not willing to confirm the Justice's Department's suspicions as to how large it is, and other manufacturers are not anxious to have their

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[188] Elliott, p. 3.

[189] *Ibid.*

[190] *Ibid.*, p. 10.

[191] *Ibid.*, p. 8.

customers know how small a portion of the market they share. Accordingly, data on computer installations and sales can only be obtained by survey of users.

The primary and perhaps the only source of such information is the International Data Corporation (IDC), Newtonville, Massachusetts. Its data is obtained through a continuing market survey, the results of which are submitted to manufacturers for voluntary confirmation. In the past, several corporations, including General Electric, IBM and Scientific Data Systems, have refused to make any comment other than that the figures were incorrect. The compilation is published in the IDC newsletter, EDP Industry and Market Report, and is sold to editors of magazines, such as Computers and Automation, for reprinting in their publications.[192] Almost any other itemization of computer installations or dollar value of shipments will reflect as its source of data the IDC or the EDP Industry and Market Report. At best, these statistics must be considered approximations.

1. The Industry

In 1947, the year following the completion of the ENIAC, only three principal sources of computer know-how existed in the United States - the laboratories at the Massachusetts Institute of Technology, the Eckert-Mauchly group, and the Engineering Research Associates. Although several machines were in the design or construction phase,

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[192] Sharpe, p. 202-203.

only two digital computers had been completed - the Mark I by M.I.T. in conjunction with IBM engineers, and the ENIAC by Professors Eckert and Mauchly.

Today, the industry is composed of nine major and several other smaller computer systems manufacturers, more than twenty manufacturers of peripheral equipment and sub-systems, over nine companies dealing in software and E.D.P. services, and at least four major companies in the computer leasing business.[193]

During the calendar year of 1969, approximately 20,000 computer systems were shipped (sold and leased) world-wide by U.S.-based manufacturers. (The output of "U.S.-based manufacturers" includes the production of U.S.-owned facilities located in foreign countries. This distinction is significant since U. S. Department of Commerce data on shipments and exports only include those originating in the United States.)[194] The cumulative number of systems in use at the end of that year was almost 90,000. As reflected in Table I, the number of systems shipped and cumulative number in use are expected to triple, to 62,000 and 272,000 respectively, by 1974.

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[193] "Office Equipment, Systems and Services - Current Analysis," Standard and Poor's Industry Surveys, 13 August 1970, p. 05-06. Hereafter cited as "Current Analysis."

[194] U. S. Industrial Outlook 1970, U. S. Department of Commerce, 1970, p. 347-348. Hereafter cited as "Outlook."

WORLD-WIDE COMPUTER ACTIVITY

OF U.S. BASED MANUFACTURERS

| | Number of Systems Shipped | Cumulative Number In Use | $ Million Value Shipped | Cumulative $ Billion Value In Use |
|---|---|---|---|---|
| E1974 | 62,200 | 272,100 | 13,400 | 70.8 |
| E1973 | 53,100 | 219,100 | 11,800 | 60.8 |
| E1972 | 42,800 | 173,900 | 10,300 | 51.7 |
| E1971 | 33,800 | 137,700 | 8,940 | 43.8 |
| E1970 | 25,100 | 109,800 | 7,720 | 36.8 |
| 1969 | 19,650 | 89,400 | 7,170 | 30.8 |
| 1968 | 14,700 | 69,400 | 7,150 | 24.6 |
| 1967 | 18,700 | 57,600 | 5,900 | 18.9 |
| 1966 | 10,200 | 40,600 | 3,660 | 13.5 |
| 1965 | 7,400 | 31,000 | 2,400 | 10.1 |

E - Estimated

Source: EDP Industry Report as reprinted in part in "Office Equipment - Basic Analysis," of Standard and Poor's Industry Surveys, 9 July 1970.

TABLE I

World-wide revenues of American-based companies from rental and sales of computers are illustrated in Table II. Revenues during 1969 rose to over $7.2 billion, an increase of approximately 12% over the previous year. Estimates of revenues through 1974 reveal an increase each year of approximately 18%.

2. The Firms

The major computer manufacturers in the United States are listed in Table III, with an indication of relative market share in 1969 as measured in terms of number of computer shipments and equipment in use. The dominant power in the industry is IBM. It has held this leading position since almost the beginning of the electronic computer era. The significance of this market concentration will be covered in more detail in Section III of the study.

The number two position in the industry will unquestionably be filled by Honeywell Information Systems (H.I.S.), the company formed by the merger of Honeywell and General Electric computer operations, although data is not yet available for the combined operation. Sperry Rand (UNIVAC), formerly number two, will be forced into third place. Rumors persist that National Cash Register (NCR) is interested in joining another company in the computer business, and is seriously considering Control Data.[195] Such as acquisition would again restructure the market concentration.

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[195] Elliott, p. 10.

WORLD-WIDE REVENUES OF

AMERICAN-BASED COMPANIES FROM

RENTALS AND SALES OF COMPUTING EQUIPMENT

| | Millions of Dollars |
|---|---|
| E1974 | 16,370 |
| E1973 | 13,900 |
| E1972 | 11,930 |
| E1971 | 10,120 |
| E1970 | 8,580 |
| 1969 | 7,210 |
| 1968 | 6,425 |
| 1967 | 4,840 |
| 1966 | 3,585 |
| 1965 | 2,790 |

E - Estimated

Source: <u>EDP Industry Report</u> reprinted in part in "Office Equipment - Basic Analysis," of Standard and Poor's <u>Industry Surveys</u>, 9 July 1970.

TABLE II

THE MAJOR U.S. COMPUTER MANUFACTURERS

WORLD-WIDE CENSUS - 1969

| Manufacturers | New Computer Shipments | | Total Equipment In Use | |
|---|---|---|---|---|
| | Sales Value*E | % of Total | Value* | % of Total |
| Burroughs | $305 | 4.3 | $980 | 3.2 |
| Control Data | 255 | 3.6 | 1,340 | 4.3 |
| Digital Equipment | 60 | 0.8 | 270 | 0.9 |
| General Electric** | 290 | 4.0 | 1,230 | 4.0 |
| Honeywell** | 340 | 4.7 | 1,320 | 4.3 |
| IBM | 4,950 | 69.0 | 21,540 | 69.8 |
| NCR | 195 | 2.7 | 690 | 2.2 |
| RCA | 230 | 3.2 | 1,050 | 3.4 |
| Sperry Rand | 400 | 5.6 | 1,810 | 5.9 |
| Xerox | 75 | 1.1 | 280 | 0.9 |
| Others | 70 | 1.0 | 360 | 1.1 |
| TOTALS | $7,170 | 100.0 | $30,870 | 100.0 |

* - Millions E - Estimated
** - Computer business acquired by H.I.S., 81% owned by Honeywell.

Source: EDP Industry and Market Report as reprinted in part in "Office Equipment - Basic Analysis," of Standard and Poor's Industry Surveys, 9 July 1970.

TABLE III

Table IV contains data from a recent issue of Barron's on shipments and installations of major U. S. computer manufacturers, and illustrates part of the problem involved in obtaining reliable, accurate information on industry concentration. Barron's used the same source of information as that used by Standard and Poor for the data appearing in Table III. Yet, significant differences exist in the respective figures with no explanation given as to how or why the data were modified. The most obvious differences are $270 million of IBM computers, $230 million of Control Data computers (one sixth of its total), and $570 million of the computers of Digital Equipment, Xerox, and others (more than half of that total).

A rapidly growing segment of the digital computer market consists of minicomputers and small computer systems. This portion of the industry generated an estimated $150 million in sales in 1969, and an increase of at least 40% in this amount is anticipated in 1970. The largest manufacturer of minicomputers is Digital Equipment, which accounted for approximately 55% of the 1969 sales. A number of other companies have entered this expanding field in 1970, including IBM with its System 3.[196]

Further analysis of corporate strength in the United States reveals the IBM is not only the leading manufacturer in the computer field, but ranks high among the industrial giants

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[196] "Basic Analysis," p. 11-12.

CURRENT READ-OUTS ON

"GENERAL PURPOSE" COMPUTER INDUSTRY WORLDWIDE

(U.S.-BASED COMPANIES ONLY)

| Company | Total Computer Equipment in Use Value* | % of Total |
|---|---|---|
| Burroughs | $990 | 3.4 |
| Control Data | 1,110 | 3.8 |
| General Electric** | 1,130 | 3.[illegible] |
| Honeywell** | 1,210 | 4.1 |
| IBM | 21,270 | 72.1 |
| National Cash Register | 690 | 2.3 |
| RCA | 1,050 | 3.6 |
| Sperry Rand | 1,730 | 5.9 |
| All Others | 340 | 1.2 |
| TOTALS | $29,520 | 100.0 |

* - Millions
** - Computer business acquired by H.I.S., 81% owned by Honeywell.

Source: Census of International Data Corporation as reprinted in part in <u>Barron's</u>, p. 10, 2 November 1970.

TABLE IV

of all industries. In 1969, IBM was the biggest U. S. corporation, as measured by stock market value, with a combined worth of all common shares of $34 billion. The next largest were American Telephone and Telegraph with $30 billion, and General Motors with $21.9 billion. For the year ending 31 December 1969, IBM ranked third in the nation in net income after taxes with $934 million. Only General Motors and Standard Oil of New Jersey ranked higher. For the same period, IBM held the fifth position in total revenue with $7.2 billion. The total assets employed in the business at the end of 1969, of $7.4 billion, earned IBM sixth place among U. S. corporations.[197]

3. The Foreign Market

Nearly $2 billion worth of new general purpose computers were installed in western Europe last year. This year, that total is expected to increase to $2.6 billion, a rate of growth of 30%. By 1980, a conservative estimate indicates that European companies will be spending $1.5 billion per month buying or leasing computers.[198]

This projection forsees a great deal of money to be made by computer manufacturers, but not necessarily by Europeans. Of the 20,000 computers currently installed in

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[197] "The Fortune Directory of the 500 Largest Industrial Corporations," _Fortune_, May 1970, p. 184. Hereafter cited as "Fortune 500, 1970."

[198] Siekman, Philip, "Now It's Europeans vrs. IBM," _Fortune_, 15 August 1969, p. 87.

western Europe, four out of five were either built in factories owned by U. S. companies, manufactured under a U. S. license, or built in the U. S. and sold in Europe with European nameplate.[199]

U. S. exports of computer systems and parts in 1969 totalled approximately $637 million, and the estimate for 1970 is near $830 million. Table V provides a breakdown as to destination of the exports for 1969.[200]

Exports, however, account for only a small portion of U.S.-based manufacturers' computer trade on foreign soil. Because exchange problems, local regulations, and other factors tend to limit shipments of equipment overseas, all major American computer firms have plants in Europe, and particularly, in Britain. IBM, for example, has two major production facilities, one in Scotland and one in England, plus a research and development laboratory in England at Hursley. Honeywell and Burroughs also have plants in England, while National Cash Register has one in Scotland.[201]

Just as in the U. S., the European computer market finds IBM in an overwhelming position of dominance. IBM plants have produced at least half of the computers now installed in western Europe.[202] In fact, some estimates claim

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[199] Ibid.

[200] Outlook, p. 348.

[201] ONRL Technical Report 27-67, The British Computer Scene, Part II: American Computer Companies in Britain, by J. Cowie, J. W. Herman, and P. D. Maycook, 17 May 1967, p. 3-4.

[202] Siekman, p. 87.

U.S. EXPORTS OF

ELECTRONIC COMPUTERS AND PARTS*

1969

| Country of Destination | Amount (Thousands) | Percent of Total |
|---|---|---|
| TOTAL | $636,499 | 100.0 |
| West Germany | 105,645 | 16.6 |
| United Kingdom | 93,951 | 14.7 |
| Canada | 92,383 | 14.5 |
| France | 80,181 | 12.6 |
| Japan | 79,630 | 12.5 |
| Hong Kong | 24,923 | 3.9 |
| Italy | 11,646 | 1.8 |
| Netherlands | 23,139 | 3.6 |
| Switzerland | 8,813 | 1.4 |
| Sweden | 13,045 | 2.0 |
| Australia | 12,824 | 2.0 |
| All Other Countries | 90,119 | 14.4 |

* - Parts accounted for 29 percent in 1969.

Source: Bureau of the Census data printed on page 348 of <u>U.S. Industrial Outlook 1970</u>, U.S. Department of Commerce, 1970.

TABLE V

that IBM possesses 80% of the non-communist computer market.[203] Britain is the only country in which another company leads IBM. As of January 1969, the International Computers Limited (ICL) had 45% of the United Kingdom market, while IBM had only 30%. The phenomenon was due partly to the early work on computers in Britain after the war, and also to the success of ICL's 1900 series computer.[204]

Other U. S. companies, with the possible exception of RCA and SDS (now Xerox-owned XDS), are employing various types of strategies to win from IBM a slice of the European computer market. Honeywell chooses to meet IBM head-on as though to say, "Anything you can do I can do better, and cheaper." Other manufacturers, on the other hand, prefer to infiltrate IBM's rare weak points, or concentrate on their own strengths. General Electric is emphasizing timesharing, a portion of its computer operation not given up in the sale to Honeywell. Burroughs deals almost exclusively in accounting machine contracts with banks. Control Data is promoting its super-computers.[205]

However, U. S. operations in Europe are not without competition. IBM and other American companies are meeting stiff opposition from European manufacturers, and the battle involves more than just a rivalry for commercial markets.

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[203] "Yapping Around IBM at Bay," The Economist, 25 January 1969, p. 67. Hereafter cited as "Yapping."

[204] Ibid.

[205] Siekman, p. 91.

Each country feels an urgent necessity to develop this industry in order to provide a technology integral to their total economy, which, for security reasons, cannot be in control of foreign countries.[206] This has lead to a push by European nations as well as Japan to develop their own computer capability.

As Alex d'Agapeyeff, managing director of a British software firm put it, this is "... not just patriotism in the stupidest sense. It is simply a question of having this central industry wholly in the hands of outsiders who can be influenced by many things including their own State Department." He was referring, of course, to an incident which occurred in 1966, when Control Data was requesting permission to export five machines to France. Two of them were directed to France's nuclear-weapons laboratory. The U. S. government refused to grant the export license until France guaranteed that none of the machine would be used in their nuclear weapons program. Naturally the incident was carefully observed throughout Europe.[207]

Currently, there are five major companies of significance in Europe - Siemens and Telefunken of Germany, Compagnie Internationale pour l'Informatique (C.I.I.), Philips of the Netherlands, Olivetti of Italy, and the British International Computers Limited. Realizing that no one of them alone could

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[206] Outlook, p. 349.

[207] Siekman, p. 87.

hope to be effective, these companies are planning a joint venture to compete with U. S. firms in the international market.[208]

Another factor that will have an effect on the international market structure is Israel's new Golem computers being developed by the Weizmann Institute of Science. Its projections call for the introduction of an advanced, giant computer sometime after 1970.[209]

In October of 1970, IBM engaged in two days of talks with the Soviet State Committee for Science and Technology to study the possibility of doing business with the Russians. While realizing the enormous amount of red tape and possible U. S. criticism involved, IBM envisioned a potential market there of several hundred million dollars. However, Russian suggestions that IBM also build a components factory within the Soviet Union were judged by IBM to be not in its best interest.[210]

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[208] Outlook, p. 349.

[209] Ibid.

[210] "Watson Dubious of Russian Market," EDP Weekly, 12 October 1970, p. 1-2.

## III. COMPUTER INDUSTRY MARKET MECHANISM

The purpose of an industry study is to examine the majority of economic and industrial literature, reports, and studies concerning the history, structure, conduct, and performance in a designated sector of the economy; it should then be possible to identify the relevant determinants of prices and output quantities in that industry's market place. Walter Adams has noted that such careful introspection of industry thought processes has been essentially an American undertaking, perhaps because of the availability of data and the persistency of the public interest. He has prologued his examination of several industry studies with the caution that merely amassing a quantity of facts relating in one way or another to an industry is not sufficient. "The difficult problem is to relate these facts to a satisfactory explanation of what has always been the primary objective of economic study in this area, prices and quantities."[211]

The unusual challenge in the preparation of this thesis is the uncharted condition of the masses of data relating to the electronic digital computer industry. That no prior industry study of computer manufacturing could be found that followed the above classic outline is not surprising. The leading cause might be the non-availability of reliable information

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[211] Adams, Walter, ed., The Structure of American Industry, Third Edition, Macmillan, 1961, p. xiii.

concerning prices and quantities, and from a review of the more serious attempts to analyze effective computer output in terms of bits or lines per dollar, nanosecond performance of instruction execution, and memory access speeds, no useful computer industry output can be synthesized. Several such studies will be examined in this section together with additional information gathered from government sources and other reports. The organization of this section will follow the outline recently published in Dr. Frederic M. Scherer's four year study of industrial organization; it is presented in Figure 1. The elements of this outline have been found to conform with the minimum considerations of other distinguished and respected authors.[212] Dr. Scherer's outline provides an excellent framework for evaluating the casual relationships which flow from the basic conditions of supply and demand throughout the market structure, to influence the conduct and performance of an industry's membership. The feedback noted by dotted lines in Figure 1, for example, is particularly important in the computer industry because of the persistency of technological growth and the resultant effect upon computer model changes. Several important aspects of this cyclic growth will be separately examined in the nature of the product, product differentiation, the importance of patents, barriers

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[212] Sharpe, W. F., Section II; see also U. S. Department of Justice letter to authors by Allen E. McAllester dated 9 October 1970; and Scherer, Frederic M., Industrial Market Structure and Economic Performance, Rand McNally, and Company, 1970, p. 8.

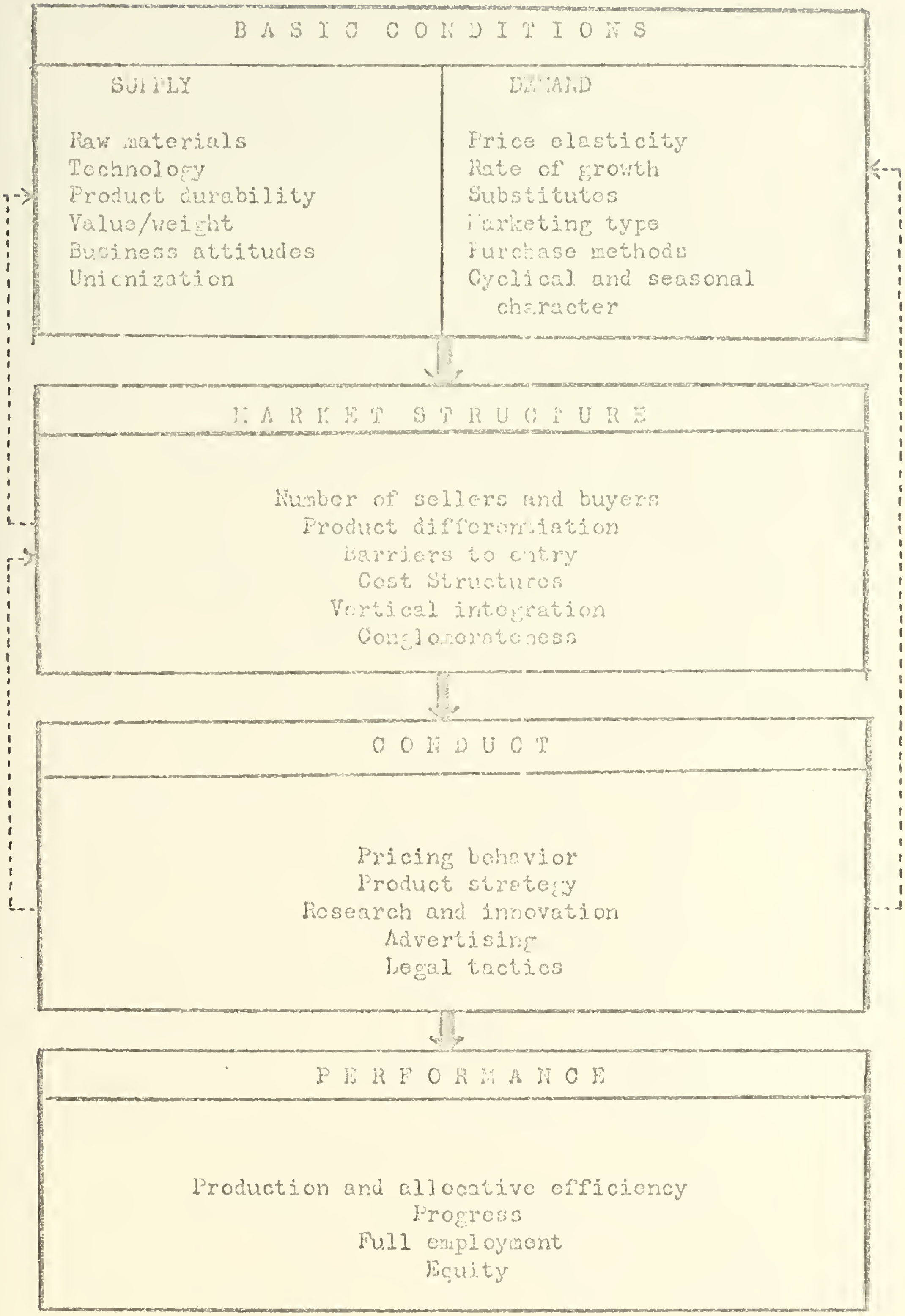
BASIC CONDITIONS
SUPPLY
Raw materials
Technology
Product durability
Value/weight
Business attitudes
Unionization
DEMAND
Price elasticity
Rate of growth
Substitutes
Marketing type
Purchase methods
Cyclical and seasonal character
MARKET STRUCTURE
Number of sellers and buyers
Product differentiation
Barriers to entry
Cost Structures
Vertical integration
Conglomerateness
CONDUCT
Pricing behavior
Product strategy
Research and innovation
Advertising
Legal tactics
PERFORMANCE
Production and allocative efficiency
Progress
Full employment
Equity

Figure 1

to entry of new firms, and indeed, in every important determinant of Market Conduct.

## A. BASIC CONDITIONS IN THE COMPUTER INDUSTRY

The basic conditions presented by Professor Scherer provide an excellent format for an analysis of the determinants of prices and output in computer manufacturing. Further, it provides a durable approach to synthesis of the industry elements into a meaningful structure, which then may be compared with such classical studies as have been prepared by Walter Adams, J. S. Bain, Richard Caves, A. D. H. Kaplan, J. B. Dirlam, R. F. Lanzillotti, R. B. Tennant, J. M. Clark, L. W. Weiss, and E. S. Mason.[213] The outline in Figure 1 is particularly interesting in respect to the computer industry, not only for the organization it makes possible, but for the elements which have not been revealed in the literature of a young industry very much discussed and analyzed. For example, virtually no reliable information is available concerning computer supply and demand data, although a large variety of essays and articles have been written which attempt to analyze the economic impact of electronic digital computers. Most of the data which is available is identified as "based on estimates", usually because the large manufacturers refuse to reveal prices and output values. Many of the sources consulted in the preparation of this section on prices and output

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[213] Scherer, p. 4; and Caves, Richard, American Industry: Structure, Conduct, Performance, Prentice-Hall, Inc., 1967, p. 116-117.

appeared to be mesmerized by the price base per unit of output in terms of bits or bytes per microsecond or nanosecond, and then relate such selected average performance to an arbitrary average rental range. Such is actually the limit of some of the better studies available on supply and demand of computers; and several will be examined in the following subsections.[214] This difficulty in being able to more accurately measure a cost-benefit relationship according to some meaningful standards, has no doubt contributed to some of the mistrust and misunderstanding by managers who employ computers; much of this problem can be traced to very poor total cost information at the time of the decision to commit an operation to the computer.[215]

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[214] Knight, Kenneth E., "A Fast Sort of Country: The Study of Technological Innovation - The Evolution of the Digital Computer," Ph.D. Dissertation, Carnegie Institute of Technology, 1964, and two published essays therefrom: "Changes in Computer Performance," Datamation, September 1966, p. 40, and "Evolving Computer Performance, 1962-1967," Datamation, January 1968, p. 33-35, these works hereafter cited, in order: "Fast," "Changes," and "Evolving;" also compare Solomon, Martin B., "Economies of Scale and the IBM System/360," Communications of the ACM, June 1966, p. 435-440, and "Economies of Scale and Computer Personnel," Datamation, March 1970, p. 107-109, both cited hereafter as "IBM," or "Personnel;" and Yourdon, Edward, "Call/360 Costs," Datamation, 1 November 1970, p. 22.

[215] Alexander, Tom, "Computers Can't Solve Everything," Fortune, October 1969, p. 126-129; and Withington, Frederic, The Real Computer: Its Influence, Uses and Effects, Addison-Wesley Publishing Co., 1969.

1. Computer Industry Supply

The many elements of supply in computer manufacturing have not been found in analyses of the professional journals, nor is that especially significant in an industry from which the product is costly and is usually manufactured as a result of a customer's order, which customer is normally another business, research firm, or a government agency. In short, finished goods inventories of computing equipment is understandably quite small, or of short duration. Many of the elements to be examined herein are not normally considered as bearing on the supply of computers. It does indeed appear that supply is not a critical subject for analysis, since the supply of computers appears to be almost unlimited. Such may explain the focus of the literature on the demand side. Nonetheless, the supply side contains several important factors which are constraints, or which are externally constrained and are determinants of output. The market mechanism on the supply side includes the costly research and development cycle, the inherently long delivery time, as a factor of production, and the backlog of customers' orders. The nature of the product includes many other limitations such as technology, and is devoid of some input constraints affecting similar industries, such as unionization. A short review of the elements of supply will thus serve a later more extensive examination of the interaction of supply and demand in the market structure.[216]

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[216] Wise, "Gamble," p. 118, and "Rocky," p. 138-140.

a. Raw Materials

An examination of the basic conditions in an industry certainly requires a consideration of the raw material input to a manufacturing process. The literature was found to highlight the innovative aspects, such as micro-miniature circuitry, but the only treatment of the spectrum of input was the aggregate form (and thus not identifiable to manufacturers or specific models or generations) found in the Department of Commerce reports, such as the "Preliminary Report of the 1967 Census of Manufactures". The Preliminary Report was published in April 1969, at which time the computer industry was included in the Standard Industrial Classification (SIC) code, 3571. Of considerable value to the many comparisons possible from the Department of Commerce's reports, and to future authors in computer industry studies, the computer industry was separately identified in the publication of the final report of the <u>1967 Census of Manufactures</u>, published in October 1970, and available under SIC code 3573. It is now possible to examine computer manufacturing in general apart from typewriters (SIC 3572), calculators and accounting machines (SIC 3574), scales and balances (SIC 3576), and office machines, not otherwise categorized (SIC 3579).[217]

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[217] U. S. Bureau of Census, "1967 Census of Manufactures, Summary Series, General Statistics," Preliminary Report (MC67(P)-1), U. S. Government Printing Office, April 1969, p. 11, hereafter cited as "Census, 1967: Summary Series;" and "1967 Census of Manufactures, Industry Series: Office, Computing, and Accounting Machines," (MC67(2)-35F), October 1970, hereafter cited as "Census, 1967: Industry Series."

Table VI lists general statistics from the most recent Annual Survey of Manufactures,[218] and it can be seen in columns G and Q, "Cost of Materials", that in 1968, computer manufacturers applied 1,985.2 million dollars to produce equipment valued at 4,151.1 million dollars. This cost includes the cost of raw materials semifinished goods, parts, components, containers, and supplies (including electrical energy), but excludes services' costs such as advertising, research and development, and consulting services. It also excludes overhead costs such as depreciation charges, rent, interest, royalties and any material or equipment used in plant expansion. The data for 1967 is also listed in Table VI, and presents a similar ratio in comparison with the output values. It will later be seen that the usefulness of this aggregated form of industry data can be demonstrated in applying market share percentages to these data, which when compared with individual manufacturers' operating statements provides a more comparable measure of costs and profits among such firms.

Table VII lists the general industrial categories of raw material input to computer manufacturing (SIC 3573) according to a six-digit product classification. It can be seen from the four largest raw material categories that most of the input components are especially made parts and attachments for computers, which by the code number (SIC 357330)

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[218] U. S. Bureau of Census, "Annual Survey of Manufactures-1968, General Statistics," (M68(AS)11), U. S. Government Printing Office, June 1970, p. 18-19, hereafter cited as "1968 Annual Survey."

## TABLE 1. General Statistics for Industry Groups

(For explanation of column

| Code | Industry group and industry | 1968 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All employees | | Production workers | | | Value added by manufacture (million dollars) | Cost of materials (million dollars) | Value of shipments (million dollars) | Capital expenditures, new (million dollars) | End-of-year inventories (million dollars) |
| | | Number (1,000) | Payroll (million dollars) | Number (1,000) | Man-hours (millions) | Wages (million dollars) | | | | | |
| | | A | B | C | D | E | F | G | H | I | J |
| | Machinery, except electrical--continued | | | | | | | | | | |
| 54 | Metalworking machinery | 324.1 | 2,849.0 | 243.0 | 523.4 | 1,953.0 | 5,004.0 | 2,462.0 | 7,485.2 | 313.8 | 1,671.4 |
| 541 | Machine tools, metal-cutting types | 83.6 | 750.7 | 56.3 | 118.8 | 459.4 | 1,357.6 | 727.7 | 2,093.1 | 63.5 | 538.7 |
| 542 | Machine tools, metal-forming types | 27.8 | 245.6 | 19.5 | 43.1 | 157.8 | 452.8 | 264.5 | 716.6 | 28.8 | 211.4 |
| 544 | Special dies, tools, jigs, and fixtures | 109.6 | 1,037.9 | 91.6 | 205.0 | 801.6 | 1,619.4 | 572.6 | 2,188.2 | 143.9 | 333.8 |
| 545 | Machine tool accessories | 57.8 | 472.5 | 42.6 | 89.6 | 315.8 | 908.1 | 406.5 | 1,312.9 | 43.5 | 275.3 |
| 548 | Metalworking machinery, n.e.c | 45.3 | 342.3 | 33.0 | 66.9 | 218.4 | 666.1 | 490.7 | 1,174.4 | 34.1 | 312.2 |
| 55 | Special industry machinery | 204.9 | 1,615.6 | 136.0 | 284.5 | 948.0 | 3,008.1 | 2,217.8 | 5,175.8 | 167.1 | 1,281.8 |
| 551 | Food products machinery | 33.1 | 259.9 | 22.0 | 44.7 | 149.7 | 514.2 | 338.1 | 841.9 | 39.7 | 205.9 |
| 552 | Textile machinery | 37.4 | 256.8 | 27.2 | 58.4 | 165.2 | 445.8 | 312.4 | 740.6 | 24.2 | 190.6 |
| 553 | Woodworking machinery | 13.3 | 93.4 | 9.1 | 18.9 | 56.1 | 209.5 | 142.5 | 350.4 | 14.2 | 74.1 |
| 554 | Paper industries machinery | 20.0 | 167.8 | 13.2 | 27.5 | 105.6 | 297.1 | 246.9 | 554.2 | 9.6 | 123.3 |
| 555 | Printing trades machinery | 30.3 | 251.7 | 20.7 | 43.0 | 155.4 | 473.0 | 346.4 | 804.2 | 27.8 | 228.0 |
| 559 | Special industry machinery, n.e.c | 70.8 | 586.0 | 43.8 | 92.0 | 316.0 | 1,068.5 | 831.5 | 1,864.3 | 51.6 | 459.7 |
| 56 | General industrial machinery | 273.0 | 2,146.5 | 190.3 | 388.2 | 1,347.1 | 4,091.3 | 2,914.8 | 6,953.1 | 360.2 | 1,600.4 |
| 561 | Pumps and compressors | 75.7 | 595.3 | 47.2 | 96.8 | 331.8 | 1,206.2 | 1,047.8 | 2,241.6 | 70.2 | 607.8 |
| 562 | Ball and roller bearings | 59.1 | 463.4 | 47.5 | 96.4 | 349.4 | 850.4 | 509.2 | 1,344.3 | 184.7 | 338.7 |
| 564 | Blowers and fans | 22.0 | 163.3 | 15.1 | 31.5 | 97.2 | 298.0 | 229.1 | 525.5 | 14.2 | 86.4 |
| 565 | Industrial patterns | 10.2 | 94.3 | 9.2 | 16.5 | 79.1 | 153.4 | 37.3 | 191.1 | (14.0) | 11.6 |
| 566 | Power transmission equipment | 53.0 | 412.0 | 39.3 | 80.8 | 270.6 | 796.5 | 488.4 | 1,278.3 | 41.8 | 298.8 |
| 567 | Industrial furnaces and ovens | 14.0 | 117.5 | 7.5 | 15.4 | 51.9 | 231.9 | 213.9 | 413.9 | 6.0 | 57.8 |
| 569 | General industrial machinery, n.e.c | 39.0 | 300.7 | 24.5 | 50.8 | 167.1 | 554.9 | 389.1 | 938.4 | 29.3 | 199.3 |
| 57 | Office and computing machines | 195.5 | 1,657.4 | 119.1 | 235.5 | 795.7 | 3,571.5 | 2,591.6 | 6,061.7 | 194.8 | 1,690.9 |
| 572 | Typewriters | 24.0 | 169.8 | 17.3 | 34.1 | 104.7 | 439.3 | 183.2 | 613.5 | 30.3 | 126.2 |
| 573 | Electronic computing equipment | 106.8 | 961.8 | 54.6 | 114.6 | 370.2 | 2,234.3 | 1,985.2 | 4,151.1 | 121.6 | 1,075.9 |
| 574 | Calculating and accounting machines | 37.5 | 324.9 | 29.5 | 52.5 | 209.3 | 459.5 | 164.6 | 607.6 | 22.6 | 305.3 |
| 576 | Scales and balances | 6.3 | 44.7 | 4.2 | 7.7 | 23.1 | 87.5 | 51.5 | 139.3 | (2.6) | 38.4 |
| 579 | Office machines, n.e.c | 20.9 | 156.2 | 13.5 | 26.6 | 88.4 | 350.9 | 207.1 | 550.2 | 17.7 | 145.1 |
| 58 | Service industry machines | 149.7 | 1,048.5 | 107.6 | 213.8 | 668.5 | 2,264.2 | 2,605.6 | 4,854.8 | 149.0 | 1,061.5 |
| 3581 | Automatic merchandising machines | 10.5 | 62.9 | 8.2 | 16.0 | 42.3 | 135.6 | 133.2 | 265.1 | 4.3 | 76.7 |
| 3582 | Commercial laundry equipment | 6.9 | 50.2 | 4.7 | 9.7 | 31.8 | 100.5 | 82.8 | 164.0 | 1.4 | 40.5 |
| 3585 | Refrigeration machinery | 103.4 | 727.2 | 75.9 | 151.1 | 480.3 | 1,576.6 | 1,996.4 | 3,562.8 | 125.2 | 781.7 |
| 3586 | Measuring and dispensing pumps | 6.5 | 46.7 | 4.5 | 9.1 | 26.5 | 105.3 | 85.4 | 187.1 | 6.7 | 44.3 |
| 3589 | Service industry machines, n.e.c | 22.4 | 161.5 | 14.3 | 27.9 | 87.6 | 348.2 | 307.8 | 655.8 | 11.4 | 118.5 |
| 3599 | Miscellaneous machinery, except electrical | 200.3 | 1,498.7 | 165.9 | 338.1 | 1,122.5 | 2,611.5 | 1,209.3 | 3,833.6 | 149.3 | 426.4 |
| 36 | Electrical equipment and supplies | 1,901.8 | 13,931.5 | 1,325.3 | 2,626.9 | 8,038.2 | 26,634.5 | 20,417.1 | 46,733.5 | 1,486.2 | 8,914.3 |
| 361 | Electric test and distributing equipment | 175.3 | 1,271.2 | 123.3 | 246.8 | 757.3 | 2,623.3 | 1,661.1 | 4,266.0 | 133.0 | 901.2 |
| 3611 | Electric measuring instruments | 61.5 | 443.2 | 40.5 | 76.7 | 230.9 | 826.6 | 412.8 | 1,228.9 | 47.1 | 309.6 |
| 3612 | Transformers | 48.9 | 358.3 | 36.5 | 74.8 | 236.1 | 783.1 | 580.2 | 1,366.9 | 44.4 | 264.0 |
| 3613 | Switchgear and switchboard apparatus | 64.9 | 469.7 | 46.3 | 93.3 | 290.3 | 1,013.4 | 668.1 | 1,670.2 | 41.5 | 327.5 |
| 362 | Electrical industrial apparatus | 208.7 | 1,500.4 | 150.7 | 301.9 | 950.4 | 2,848.6 | 1,944.9 | 4,802.3 | 192.0 | 940.3 |
| 3621 | Motors and generators | 107.3 | 764.9 | 80.5 | 163.9 | 511.1 | 1,405.9 | 991.7 | 2,403.9 | 92.2 | 445.2 |
| 3622 | Industrial controls | 53.2 | 382.4 | 34.6 | 67.8 | 211.7 | 731.9 | 401.7 | 1,145.3 | (49.7) | 235.9 |
| 3623 | Welding apparatus | 14.7 | 136.1 | 9.9 | 20.5 | 81.3 | 265.7 | 245.8 | 513.9 | 16.7 | 99.3 |
| 3624 | Carbon and graphite products | 11.8 | 63.5 | 9.1 | 17.9 | 58.7 | 188.3 | 117.4 | 302.9 | 22.8 | 73.4 |
| 3629 | Electrical industrial apparatus, n.e.c | 21.7 | 133.5 | 16.6 | 31.8 | 87.6 | 256.8 | 185.3 | 436.3 | 10.6 | 86.5 |
| 363 | Household appliances | 171.1 | 1,183.8 | 137.6 | 270.9 | 849.2 | 2,880.0 | 3,022.2 | 5,915.9 | 126.1 | 988.6 |
| 3631 | Household cooking equipment | 20.5 | 142.4 | 16.3 | 34.1 | 99.4 | 301.5 | 329.2 | 628.5 | 15.7 | 116.0 |
| 3632 | Household refrigerators and freezers | 51.8 | 396.9 | 43.0 | 84.5 | 305.4 | 889.4 | 1,087.7 | 1,978.5 | 33.6 | 312.1 |
| 3633 | Household laundry equipment | 23.5 | 174.0 | 19.2 | 36.9 | 130.6 | 499.9 | 598.7 | 1,097.0 | 26.0 | 140.1 |
| 3634 | Electric housewares and fans | 44.5 | 251.9 | 35.6 | 69.0 | 161.5 | 634.9 | 547.0 | 1,193.1 | 22.6 | 229.3 |
| 3635 | Household vacuum cleaners | 10.1 | 67.7 | 7.7 | 14.5 | 46.5 | 208.4 | 133.1 | 339.0 | 9.9 | 60.3 |
| 3636 | Sewing machines | 6.0 | 45.8 | 4.6 | 9.2 | 33.0 | 86.4 | 35.0 | 130.2 | 4.1 | 43.8 |
| 3639 | Household appliances, n.e.c | 14.7 | 105.1 | 11.2 | 22.7 | 69.8 | 259.5 | 291.5 | 549.6 | 14.0 | 87.0 |
| 364 | Electric lighting and wiring equipment | 166.4 | 1,058.9 | 131.0 | 260.7 | 716.7 | 2,479.0 | 1,791.6 | 4,181.9 | 136.2 | 685.6 |
| 3641 | Electric lamps | 31.0 | 187.7 | 27.0 | 52.7 | 149.3 | 588.8 | 278.2 | 860.2 | 37.9 | 90.8 |
| 3642 | Lighting fixtures | 67.6 | 430.8 | 51.9 | 104.2 | 278.4 | 924.8 | 834.2 | 1,749.8 | 49.0 | 273.3 |
| 3643 | Current carrying wiring devices | 44.0 | 264.9 | 34.7 | 67.7 | 171.6 | 568.2 | 379.9 | 919.6 | 27.7 | 174.2 |
| 3644 | Noncurrent carrying wiring devices | 23.6 | 175.5 | 17.4 | 36.1 | 114.4 | 397.2 | 299.3 | 622.3 | (21.6) | 147.3 |
| 365 | Radio and TV receiving equipment | 127.1 | 750.0 | 103.5 | 199.5 | 528.8 | 1,750.7 | 2,791.1 | 4,588.2 | 41.8 | 693.8 |
| 3651 | Radio and TV receiving sets | 112.8 | 665.9 | 92.3 | 176.1 | 469.7 | 1,543.1 | 2,685.9 | 4,272.4 | 36.4 | 656.9 |
| 3652 | Phonograph records | 14.3 | 64.1 | 11.2 | 23.4 | 59.1 | 207.6 | 105.2 | 315.8 | 5.4 | 36.9 |

See footnotes at end of table.

Table VI

## and Industries: 1968 and 1967–Continued

captions, see appendix)

| 1967[1] | | | | | | | | | | Standard error of estimate (percent) for columns[2]– | | | Code |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All employees | | Production workers | | | Value added by manufacture | Cost of materials | Value of shipments | Capital expenditures, new | End-of-year inventories | | | | |
| Number (1,000) | Payroll (million dollars) | Number (1,000) | Man-hours (millions) | Wages (million dollars) | (million dollars) | (million dollars) | (million dollars) | (million dollars) | (million dollars) | | | | |
| K | L | M | N | O | P | Q | R | S | T | A | F | I | |
| 334.2 | 2,833.4 | 254.0 | 556.1 | 1,966.5 | 5,044.7 | 2,510.2 | 7,442.0 | 318.2 | 1,586.6 | 4 | 1 | 6 | 354 |
| 86.9 | 757.3 | 60.3 | 131.5 | 475.1 | 1,389.4 | 767.4 | 2,127.5 | 78.9 | 535.4 | 2 | 1 | 2 | 3541 |
| 28.9 | 247.4 | 20.7 | 45.7 | 163.7 | 429.9 | 286.2 | 698.6 | 24.7 | 202.6 | 6 | 3 | 8 | 3542 |
| 111.6 | 1,013.1 | 94.0 | 213.6 | 785.6 | 1,608.9 | 561.7 | 2,151.1 | 113.1 | 240.2 | 4 | 1 | 7 | 3544 |
| 59.8 | 475.7 | 44.8 | 95.5 | 321.8 | 916.7 | 413.2 | 1,300.2 | 54.7 | 272.1 | 1 | 1 | 8 | 3545 |
| 47.0 | 339.9 | 34.2 | 69.8 | 220.3 | 699.8 | 481.7 | 1,164.6 | 46.8 | 336.3 | 4 | 2 | 6 | 3548 |
| 206.8 | 1,575.2 | 140.5 | 295.2 | 947.0 | 2,865.9 | 2,164.2 | 4,962.2 | 178.3 | 1,250.3 | 1 | 1 | 4 | 355 |
| 32.3 | 248.6 | 21.8 | 45.0 | 146.6 | 499.5 | 336.0 | 824.8 | 21.9 | 197.7 | 1 | 2 | 10 | 3551 |
| 39.6 | 252.3 | 29.3 | 62.2 | 168.4 | 404.9 | 308.9 | 712.5 | 22.2 | 185.3 | 1 | 1 | 14 | 3552 |
| 12.6 | 83.7 | 8.7 | 17.6 | 50.3 | 190.8 | 128.0 | 314.0 | 8.2 | 70.7 | 1 | 1 | 6 | 3553 |
| 21.6 | 175.1 | 14.6 | 31.2 | 111.9 | 285.9 | 270.7 | 560.0 | 19.1 | 136.8 | 1 | 1 | 10 | 3554 |
| 29.1 | 239.2 | 20.1 | 42.1 | 146.8 | 458.0 | 324.1 | 750.9 | 32.9 | 217.5 | 1 | 1 | 2 | 3555 |
| 71.6 | 576.3 | 46.0 | 97.1 | 321.0 | 1,026.8 | 796.5 | 1,800.0 | 74.0 | 442.3 | 1 | 2 | 5 | 3559 |
| 278.9 | 2,132.8 | 196.7 | 410.4 | 1,354.5 | 4,107.3 | 2,909.7 | 6,930.8 | 296.4 | 1,552.8 | 1 | 1 | 3 | 356 |
| 78.7 | 591.7 | 50.2 | 105.3 | 336.8 | 1,216.8 | 1,040.7 | 2,224.4 | 63.4 | 592.1 | 1 | 1 | 10 | 3561 |
| 59.1 | 457.9 | 47.6 | 101.2 | 344.8 | 839.5 | 512.0 | 1,335.7 | 107.8 | 318.8 | 1 | 1 | 1 | 3562 |
| 21.6 | 152.7 | 15.5 | 32.6 | 96.1 | 305.0 | 225.1 | 530.2 | 14.4 | 84.7 | 3 | 2 | 12 | 3564 |
| 10.9 | 106.5 | 9.5 | 19.4 | 87.0 | 166.1 | 37.4 | 202.9 | 8.1 | 12.7 | 10 | 6 | 32 | 3565 |
| 54.3 | 407.0 | 40.3 | 82.9 | 272.7 | 795.6 | 481.3 | 1,256.8 | 56.9 | 286.0 | 1 | 1 | 4 | 3566 |
| 15.0 | 122.0 | 8.1 | 16.7 | 53.6 | 244.5 | 230.6 | 472.7 | 15.2 | 63.1 | 2 | 1 | 15 | 3567 |
| 39.3 | 295.0 | 25.5 | 52.3 | 163.5 | 539.8 | 382.6 | 908.1 | 30.6 | 195.4 | 2 | 1 | 2 | 3569 |
| 189.6 | 1,455.9 | 119.1 | 236.1 | 754.2 | 3,324.3 | 2,465.5 | 5,717.3 | 192.3 | 1,474.6 | 1 | 1 | 1 | 3572 |
| 26.0 | 172.3 | 19.9 | 39.3 | 116.7 | 455.0 | 155.3 | 596.0 | 20.1 | 114.0 | 1 | 1 | 1 | 3572 |
| 98.2 | 798.3 | 50.3 | 103.5 | 312.6 | 1,920.7 | 1,669.6 | 3,760.8 | 116.6 | 980.8 | 1 | 1 | 1 | 3573 |
| 38.4 | 294.4 | 31.3 | 58.6 | 219.7 | 518.2 | 198.2 | 707.8 | 32.6 | 206.8 | 1 | 1 | 7 | 3574 |
| 6.5 | 45.6 | 4.3 | 8.5 | 24.0 | 90.0 | 51.3 | 140.2 | 5.1 | 36.1 | 5 | 6 | 20 | 3576 |
| 20.5 | 145.3 | 13.3 | 26.2 | 81.2 | 340.4 | 191.1 | 512.5 | 17.9 | 136.9 | 2 | 4 | 5 | 3579 |
| 141.6 | 959.6 | 102.4 | 206.3 | 614.5 | 2,141.7 | 2,331.9 | 4,390.6 | 145.0 | 1,024.0 | 2 | 1 | 1 | 358 |
| 10.0 | 59.2 | 7.8 | 14.8 | 39.6 | 140.8 | 122.5 | 248.0 | 5.5 | 81.6 | 1 | 1 | 2 | 3581 |
| 7.5 | 50.9 | 5.4 | 11.2 | 32.5 | 96.4 | 85.9 | 183.0 | 4.9 | 41.6 | 1 | 2 | 14 | 3582 |
| 97.6 | 660.1 | 71.8 | 145.2 | 438.7 | 1,506.1 | 1,760.9 | 3,207.5 | 120.2 | 745.0 | 1 | 1 | 1 | 3585 |
| 6.4 | 45.5 | 4.3 | 8.9 | 25.0 | 96.6 | 80.6 | 174.3 | 3.8 | 43.6 | 1 | 1 | 1 | 3586 |
| 20.1 | 143.9 | 13.1 | 26.2 | 78.7 | 301.8 | 282.0 | 577.8 | 10.6 | 112.2 | 2 | 1 | 13 | 3589 |
| 202.2 | 1,439.4 | 168.5 | 346.6 | 1,090.4 | 2,525.5 | 1,192.5 | 3,701.4 | 178.6 | 370.4 | 2 | 1 | 7 | 3599 |
| 1,897.1 | 13,129.0 | 1,338.5 | 2,643.8 | 7,683.6 | 24,844.7 | 19,580.7 | 43.896.4 | 1,562.2 | 8,599.6 | 1 | 1 | 2 | 36 |
| 178.5 | 1,251.4 | 126.3 | 251.9 | 751.5 | 2,556.1 | 1,630.8 | 4,139.6 | 146.9 | 884.9 | 1 | 1 | 1 | 361 |
| 62.4 | 431.0 | 41.2 | 80.2 | 228.3 | 809.5 | 399.5 | 1,196.5 | 54.1 | 297.4 | 2 | 1 | 1 | 3611 |
| 47.6 | 331.6 | 35.6 | 71.5 | 219.1 | 719.6 | 561.4 | 1,257.1 | 54.0 | 248.5 | 1 | 1 | 2 | 3612 |
| 68.5 | 488.8 | 49.5 | 100.2 | 304.1 | 1,026.8 | 669.9 | 1,686.0 | 38.8 | 339.0 | 1 | 1 | 1 | 3613 |
| 208.2 | 1,427.7 | 153.8 | 309.6 | 928.8 | 2,792.2 | 1,870.5 | 4,630.5 | 207.3 | 921.4 | 1 | 1 | 11 | 362 |
| 110.3 | 750.4 | 83.5 | 168.9 | 504.7 | 1,406.0 | 962.4 | 2,363.6 | 100.8 | 443.3 | 1 | 1 | 1 | 3621 |
| 50.9 | 354.7 | 35.0 | 70.0 | 211.7 | 722.8 | 390.1 | 1,105.1 | 34.9 | 227.5 | 2 | 1 | 41 | 3622 |
| 14.0 | 120.7 | 9.6 | 20.2 | 74.5 | 256.3 | 237.4 | 485.4 | 18.2 | 99.9 | 4 | 2 | 14 | 3623 |
| 11.9 | 82.8 | 9.1 | 18.5 | 57.8 | 186.3 | 117.8 | 296.4 | 41.3 | 69.4 | 2 | 1 | 1 | 3624 |
| 21.1 | 119.1 | 16.6 | 32.0 | 80.1 | 218.8 | 162.8 | 379.0 | 12.1 | 81.3 | 4 | 3 | 4 | 3629 |
| 168.2 | 1,088.9 | 134.1 | 261.0 | 778.5 | 2,543.4 | 2,762.7 | 5,278.7 | 118.0 | 977.7 | 1 | 1 | 1 | 363 |
| 20.2 | 127.9 | 15.9 | 32.4 | 88.4 | 254.0 | 291.6 | 549.7 | 8.6 | 107.0 | 1 | 1 | 4 | 3631 |
| 50.0 | 357.8 | 41.3 | 79.4 | 273.5 | 769.4 | 959.0 | 1,695.0 | 25.9 | 308.5 | 1 | 1 | 1 | 3632 |
| 22.2 | 154.2 | 17.8 | 33.7 | 113.9 | 408.5 | 562.3 | 962.5 | 31.8 | 138.6 | 1 | 1 | 1 | 3633 |
| 45.0 | 241.8 | 35.9 | 69.8 | 163.0 | 597.0 | 519.0 | 1,118.9 | 27.2 | 232.7 | 1 | 1 | 2 | 3634 |
| 10.0 | 62.3 | 7.6 | 14.2 | 42.3 | 192.1 | 123.5 | 308.1 | 7.4 | 59.9 | 1 | 1 | 1 | 3635 |
| 6.4 | 49.3 | 4.9 | 9.7 | 34.7 | 95.3 | 30.0 | 123.6 | 5.6 | 51.2 | 1 | 1 | 3 | 3636 |
| 14.4 | 95.6 | 10.7 | 21.8 | 62.7 | 227.1 | 277.3 | 500.9 | 11.5 | 79.8 | 1 | 1 | 3 | 3639 |
| 160.6 | 967.0 | 126.2 | 248.8 | 656.4 | 2,254.9 | 1,670.7 | 3,912.4 | 136.3 | 638.5 | 1 | 1 | 4 | 364 |
| 29.5 | 169.9 | 25.8 | 49.9 | 136.0 | 537.7 | 248.4 | 781.8 | 48.2 | 83.7 | 1 | 1 | 1 | 3641 |
| 64.9 | 389.6 | 50.2 | 99.2 | 253.8 | 832.6 | 773.5 | 1,602.2 | 32.9 | 248.7 | 1 | 1 | 7 | 3642 |
| 43.0 | 248.8 | 33.2 | 65.5 | 164.5 | 538.2 | 354.0 | 891.9 | 34.4 | 169.2 | 1 | 1 | 1 | 3643 |
| 23.2 | 158.7 | 17.0 | 34.2 | 102.1 | 346.4 | 294.8 | 636.5 | 20.8 | 136.9 | 3 | 2 | 19 | 3644 |
| 129.6 | 715.8 | 106.7 | 204.5 | 514.0 | 1,576.7 | 2,576.2 | 4,107.3 | 93.2 | 761.8 | 1 | 1 | 2 | 365 |
| 116.2 | 640.0 | 95.8 | 182.5 | 460.5 | 1,396.6 | 2,452.1 | 3,834.1 | 86.1 | 723.8 | 1 | 1 | 2 | 3651 |
| 13.4 | 75.8 | 10.9 | 22.0 | 53.5 | 180.1 | 94.1 | 273.2 | 7.1 | 38.0 | 1 | 1 | 1 | 3652 |

Table VI (continued)

# TABLE 7A. Materials Consumed, by Kind: 1967 and 1963

(See Appendix, Explanation of Terms)

| Code | Material | Unit of measure | 1967 Quantity | 1967 Delivered cost (million dollars) | 1963 Quantity | 1963 Delivered cost (million dollars) |
|---|---|---|---|---|---|---|
| | INDUSTRY 3572.--TYPEWRITERS | | | | | |
| | Materials, parts, containers, and supplies, total | ................ | (X) | 146.6 | (X) | 73.9 |
| | Mill shapes and forms (except castings): | | | | | |
| | Carbon steel: | | | | | |
| 331011 | Bars and bar shapes | 1,000 short tons. | | | 5.9 | 1.5 |
| 331012 | Sheet and strip | ...do | | | 20.2 | 5.3 |
| 331017 | Wire and wire products | ...do | | | 1.7 | 0.4 |
| 331015 | Structural shapes | ...do | 30.0 | 8.7 | 0.8 | 0.3 |
| 331019 | All other carbon steel mill shapes and forms | ...do | | | | |
| 331020 | Alloy steel (except stainless) | ...do | | | 0.5 | 0.3 |
| 331031 | Stainless steel | ...do | | - | 0.1 | 0.2 |
| | Copper and copper-base alloy: | | | | | |
| 335728 | Bare wire (For electrical conduction only) | million lbs | (1) | (1) | (NA) | (NA) |
| 335790 | Insulated wire and cable | million lbs. copper content | (1) | (1) | (1) | (1) |
| 335102 | Rod, bar, and mechanical wire, including extruded and/or drawn shapes | million lbs | | | | |
| 335123 | Plate, sheet, and strip (including military cups and discs) | ...do | (1) | (1) | (1) | (1) |
| 335127 | Pipe and tube | ...do | | | | |
| | Aluminum and aluminum-base alloy: | | | | | |
| 335205 | Extruded shapes (including extruded rod, bar, pipe, tube, etc.) | ...do | | | 0.8 | 0.7 |
| 335202 | Sheet, plate, and foil | ...do | 2.2 | 1.9 | | |
| 335209 | All other aluminum mill shapes and forms (wire, rolled rod and bar powder, welded tubing) | ...do | | | 0.6 | 0.3 |
| | Castings (rough and semifinished):[2] | | | | | |
| 332300 | Steel | 1,000 short tons. | 1.2 | 0.7 | 3.0 | 1.5 |
| 336100 | Aluminum and aluminum-base alloy | million lbs | 1.8 | 1.9 | 4.5 | 3.7 |
| | Electric motors and generators:[2] | | | | | |
| | Fractional horsepower electric motors (under 1 hp.): | | | | | |
| 362110 | Timing motors, synchronous and subsynchronous | 1,000 | | | (1) | (1) |
| 362115 | Fractional horsepower electric motors (excluding timing motors) | ...do | 1,359.9 | 5.8 | 688.3 | 4.1 |
| 362120 | Integral horsepower motors and generators (1 h.p. and over) | ...do | - | - | (NA) | (NA) |
| | Bearings: | | | | | |
| 356218 | Ball | ................ | (X) | (1) | (X) | 0.5 |
| 356201 | Roller | ................ | | | | |
| 367010 | Electron tubes, except X-ray[2] | million | (1) | (1) | (1) | (1) |
| 367408 | Solid state semiconductors[2] | ...do | (1) | (1) | (1) | (1) |
| 367901 | Resistors, capacitors, transformers, sockets, and other electronic components and accessories, except solid state semiconductors | ................ | (X) | (1) | (X) | (NA) |
| 970099 | All other materials and components, parts, containers, and supplies consumed | ................ | (X) | 100.3 | (X) | 53.7 |
| 976000 | Materials and components, n.s.k.[3] | ................ | (X) | 27.3 | (X) | 1.5 |

| Code | Material | Unit of measure | 1967 Industry 3573.--Electronic computing equipment: Quantity | Delivered cost (million dollars) | 1967 Industry 3574.--Calculating and accounting machines: Quantity | Delivered cost (million dollars) | 1963 Industries 3573 and 3574.--Computing and related machines: Quantity | Delivered cost (million dollars) |
|---|---|---|---|---|---|---|---|---|
| | Start SIC 3573 | | | | | | | |
| | Materials, parts, containers, and supplies, total | ................ | (X) | [4]1,768.1 | (X) | 141.3 | (X) | [4]1,388.7 |
| | Mill shapes and forms (except castings): | | | | | | | |
| | Carbon steel: | | | | | | | |
| 3 011 | Bars and bar shapes | 1,000 short tons. | 1.8 | 0.8 | (5) | (5) | 11.0 | 3.2 |
| 3 012 | Sheet and strip | ...do | (NA) | 5.8 | 30.1 | 7.6 | 22.9 | 5.6 |
| 3 015 | Structural shapes | ...do | (6) | (6) | | | 1.4 | 0.4 |
| 3 017 | Wire and wire products | ...do | 2.9 | 3.6 | | | 0.2 | 0.3 |
| 3 019 | All other carbon steel mill shapes and forms | ...do | [6]6.7 | [6]2.1 | [5]13.6 | [5]4.4 | 2.1 | 0.7 |
| 3 020 | Alloy steel (except stainless) | ...do | 2.1 | 3.1 | | | 2.5 | 2.0 |
| 3 031 | Stainless steel | ...do | | | | | 0.8 | 1 2 |

See footnotes at end of table.

Table VII

## TABLE 7A. Materials Consumed, by Kind: 1967 and 1963—Continued

(See Appendix, Explanation of Terms)

| Material | Unit of measure | 1967: INDUSTRY 3573.--ELECTRONIC COMPUTING EQUIPMENT--Con. Quantity | 1967: INDUSTRY 3573 Delivered cost (million dollars) | 1967: INDUSTRY 3574.--CALCULATING AND ACCOUNTING MACHINES--Con. Quantity | 1967: INDUSTRY 3574 Delivered cost (million dollars) | 1963: INDUSTRIES 3573 AND 3574.--COMPUTING AND RELATED MACHINES--Con. Quantity | 1963: INDUSTRIES 3573 AND 3574 Delivered cost (million dollars) |
|---|---|---|---|---|---|---|---|
| Materials, parts, containers, and supplies,--Continued | | | | | | | |
| Mill shapes and forms (except castings)--Continued | | | | | | | |
| Copper and copper-base alloy: | | | | | | | |
| Bare wire for electrical conduction | Million lbs | (1) | (1) | (1) | (1) | 5.7 | 4.4 |
| Insulated wire and cable | Million lbs. (copper content) | (NA) | 39.0 | (1) | (1) | | |
| Rod, bar, and mechanical wire, including extruded an/or drawn shapes | Million lbs | 0.5 | 0.6 | (1) | (1) | 0.8 | 0.5 |
| Plate, sheet, and strip (including military cups and discs) | ...do | | | (1) | (1) | 2.4 | 2.9 |
| Pipe and tube | ...do | 0.1 | 0.1 | (1) | (1) | 0.3 | 0.3 |
| Aluminum and aluminum-base alloy: | | | | | | | |
| Sheet, plate and foil | ...do | 8.9 | 8.4 | 3.6 | 2.0 | 1.9 | 1.4 |
| Extruded shapes (including extruded rod, bar, pipe tube, etc.) | ...do | | | | | 1.6 | 1.1 |
| All other aluminum mill shapes and forms (wire, rolled rod and bar, powder, welded tubing, etc.) | ...do | | | | | 0.7 | 0.4 |
| Castings (rough and semifinished):[2] | | | | | | | |
| Steel | 1,000 short tons | (NA) | 2.8 | (1) | (1) | 0.6 | 0.6 |
| Aluminum and aluminum-base alloy | Million lbs | 3.2 | 4.1 | (1) | (1) | 2.7 | 3.2 |
| Electric motors and generators:[2] | | | | | | | |
| Fractional horsepower electric motors (under 1 hp.): | | | | | | | |
| Timing motors, synchronous and subsynchronous | 1,000 | (NA) | 4.7 | 214.3 | 0.5 | (NA) | 1.6 |
| Other fractional horsepower electric motors | ...do | (1) | (1) | (1) | (1) | 353.2 | 7.9 |
| Integral horsepower motors and generators (1 hp. and over) | ...do | (1) | (1) | (1) | (1) | 13.0 | 4.1 |
| Bearings: | | | | | | | |
| Ball | | (X) | 4.1 | (X) | (1) | (X) | 3.1 |
| Roller | | | | (X) | (1) | (X) | 0.2 |
| Electron tubes, except X-ray[2] | Millions | 0.5 | 1.0 | (1) | (1) | 1.1 | 2.5 |
| Solid state semiconductors[2] | ...do | 348.4 | 141.4 | 92.2 | 13.4 | 257.2 | 100.8 |
| Resistors, capacitors, transformers, sockets, and other electronic components and accessories, except solid state semiconductors | | (X) | 205.7 | (X) | 12.2 | (X) | 1,215.8 |
| Parts and attachments specially designed for electronic computing equipment | | (X) | 688.7 | (X) | (1) | (X) | |
| All other materials and components, parts, containers, and supplies consumed | | (X) | 622.6 | (X) | 89.4 | (X) | |
| Materials and components, n.s.k.[3] | | (X) | 29.5 | (X) | 11.8 | (X) | 24.3 |

| Material | Unit of measure | 1967 Quantity | 1967 Delivered cost (million dollars) | 1963 Quantity | 1963 Delivered cost (million dollars) |
|---|---|---|---|---|---|
| INDUSTRY 3576.--SCALES AND BALANCES | | | | | |
| Materials, parts, containers, and supplies, total | | (X) | 46.9 | (X) | 32.0 |
| Mill shapes and forms (except castings): | | | | | |
| Carbon steel: | | | | | |
| Bars and bar shapes | 1,000 Short tons | 2.0 | 0.5 | 2.1 | 0.5 |
| Sheet and strip | ...do | 17.5 | 3.1 | 22.5 | 3.5 |
| Structural shapes | ...do | 5.8 | 1.0 | 4.7 | 0.9 |
| Wire and wire products | ...do | 1.7 | 0.4 | 0.1 | (Z) |
| All other carbon steel mill shapes and forms | ...do | | | 2.1 | 0.5 |
| Alloy steel (except stainless) | ...do | 0.6 | 0.9 | 0.1 | 0.1 |
| Stainless steel | ...do | | | 0.4 | 0.6 |
| Copper and copper-base alloy: | | | | | |
| Bare wire (for electrical conduction only) | Million lbs | (Z) | (Z) | (NA) | (NA) |
| Insulated wire and cable | Million lbs copper content | (1) | (1) | (1) | (1) |
| Rod, bar, and mechanical wire, including extruded and/or drawn shapes | Million lbs | (1) | (1) | (1) | (1) |
| Plate, sheet, and strip (including military cups and discs) | ...do | | | | |
| Pipe and tube | ...do | | | | |

Footnotes at end of table.

happens to also be made in the computer industry. The value is 688.7 million dollars of the total 1,768.1 million dollars for this 1967 census data; the electronics industry as a supplier to the computer manufacturers supplied only 248.1 million dollars of that total. The electronics industry is identified by SIC codes which have the first three digits as 367--- in Table VII.[219]

It is appropriate at this point to note as a convention in this section, that reference is made to dollar values as above, in the millions rather than in billions because of the variance between the American and British systems. A more complete description of the Standard Industrial Classification (SIC) system will be provided in a later section when it becomes necessary to distinguish among the various industry classifications.

b. Technology

The growth of technology in the computer industry has been significant in extending the power of the computer, and, on the demand side, in determining the overall growth rate of the computer industry. There are several interesting definitions of computer generations, but one is based on technological breakthroughs which affect the supply side in the form of new models or new families of computers. Some of the technological growth which has precipitated new families or generations of computers actually were achieved in the electronics industry, for example, the transition from vacuum

[219] "Census, 1967: Industry Series," p. 21-22.

tubes to transistors between 1951 and 1960.[220] During that transition, IBM was fortunate to have hired Dr. Emanuel Piore, former head of U. S. Navy Research, because important technological decisions were before the IBM Logic Committee. That committee had the task of deciding between two leading technologies for the System 360 hardware design: Monolithic Integrated Circuitry, and Hybrid Integrated Circuitry.[221] Monolithic integrated circuitry meant placing all the essential elements of a given circuit into one chip at the same time (transistors, resistors, connectors and diodes). The alternate technology, dubbed "solid logic technology" by IBM at that time, meant soldering the circuit elements onto a card.

In 1961, IBM decided to avoid the uncertainties and developmental risks of the monolithic circuits being ready in time for the planned 1964 introduction of the System 360 computers. The decision to pursue the hybrid circuit board technology was apparently not popular in all technical circles inside or outside IBM, because there was a question as to whether the "state of the art" would thereby be advanced. There was also the criticism that development of the hybrid integrated circuits would eventually leave IBM frozen into a technology that would be more costly in obsolescence before its cost could be recovered. Nonetheless, Watson referred to the choice as "the most fortunate decision we ever made."[222]

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[220] Wise, "Gamble," p. 139.

[221] Ibid., p. 139-141.

[222] Ibid., p. 142.

The prospect of developing an advanced scientific design concept, at that time, which if successful, the monolithic chip would also contain some of the innermost secrets of IBM's circuitry design, did not provide appropriate protection for patentable achievements. IBM had not been making significant quantities of the basic components and would thus continue to rely upon such leading component suppliers as Texas Instruments to provide the advanced monolithic chips; such suppliers would thus also have access to the monolithic production trade secrets and the IBM circuit design characteristics. The System 360 family of computers would eventually feature the monolithic circuitry in such advanced designs as the 360/85, however the initial decision concerning technologies favored the one which offered the better probability of completion on time, with fewer patent obstacles in product design as well as process innovations. It is still a subject of debate as to whether IBM continued active development of the monolithic technology, however no external announcements of the monolithic design for the later System 360 models is observed until after the family was first introduced in April 1964. Later in 1964, RCA announced the intended use of the pure monolithic integrated circuitry in some of the models of its Spectra 70 line. By that time, IBM was an experienced component manufacturer, with the capability to shift technologies if an operational advantage could be demonstrated, with attendent competitive impetus.

Nonetheless, IBM developed the solid logic circuitry for the System 360 hardware design, and at the time of the 1964

announcements, Tom Watson, Jr. remarked:

"Too much proprietary information was involved in circuitry production ... Unless we did it ourselves, we could be turning over some of the essentials of our business to another group."[223]

Thus technology as a proprietary factor of production required more protection than could be assured by the patenting process, and IBM found it necessary to seriously enter the manufacture of its own components used in the making of computers. Actually, former IBM president, Al Williams, had urged such a move in 1960, and in 1962 IBM authorized the construction of a new plant to make components. The general manager of the component manufacturing division was John Gibson, a doctoral graduate of Johns Hopkins in electrical engineering. The new division was to have the authority to decide what components to make, and it was outfitted with the latest automatic equipment valued at $100 million dollars.[224] The expense of installing automatic equipment would be recovered in labor cost savings.

With the present advent of the fourth generation in computers, and another generation of technology this time in integrated circuitry referred to as "large scale", the same proprietary interest in the preservation of circuit information has had a continuing effect on computer manufacturers to produce their own semiconductors and integrated circuits. By way of progress report on third generation accomplishments, and as an indicator of fourth generation plans, Business Week

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[223] Ibid., p. 166.

[224] Ibid., p. 166, 192.

reported that IBM has become the second or third largest manufacturer of semiconductors; and the trend of computer manufacturers making their own integrated circuits is expected to intensify.[225] _Business Week_ continued:

> "The trend to integrated circuits is forcing computer makers into semiconductor design--perhaps irreversibly. They could wire the simpler transistor into any kind of circuit design. But integrated circuits are completely wired up circuit functions, so new computer design depends more on semiconductor manufacturing than on assembly-type operations. Semiconductors now account for up to 50% of a computer's cost, and their share is growing."

The latter percentage may be high inasmuch as the _Census of Manufactures_ listed the 1963 solid state semiconductor input (SIC 367408) as 101 million dollars as compared to a total delivered cost under the old SIC 3571 of 847 million dollars. The 847 million dollar figure was published in the Department of Commerce's 1963 _Census of Manufactures_, but when the same data was recently republished with the _1967 Census of Manufactures_ it was increased to 1,388.7 million dollars for 1963. That unexplained difference does nothing to help explain a fifty per cent figure found by _Business Week_, even though some part could be explained by an "all other" category (SIC 970099), or by a category for parts and attachments made especially for computers. This category is listed in Table VI for 1967 as SIC 357330, and for 1963 data as SIC 35710. As previously noted, these categories are made within the computer industry. A summary of the semiconductor costs in relation to the "materials consumed by kind" total input costs

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225 "TI Tilts at IBM's Market," _Business Week_, 27 June 1970, p. 80.

as reported in the Department of Commerce reports for the years of manufactures census, 1958, 1963, and 1967 is appropriate.[226]

The material contained in Table VIII is necessarily general, however it indicated that the trend is that lesser amounts of semiconductors have been received by computer manufacturers from outside the industry; although it did not reflect an increasing trend within a newly numbered "special parts" category as might be expected since that category of parts and attachments is produced within the computer industry. The most recent reports from which the information in Table VIII was obtained document the fact that some information had to be retained in a collective "all other" category to prevent the disclosure of individual companies.

The rapid advance of technology in computer manufacturing throughout the 1960's witnessed the main frame central processing units (CPU) far exceeding the capability of processing speeds in the input/output equipment and secondary memory. This gap in technology has continued to plague and delay effective time-sharing, even though major advances in input/output channel organization have enabled continued market development, which, in 1967 was being served by about 80% by General Electric.[227] In a like manner, peripheral equipment development required heavy Research and Development expenditures in

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[226] "Census, 1967: Industry Series", p. 21-22; and U. S. Bureau of Census, "1963 Census of Manufacturers, Industry Series", U. S. Government Printing Office, 1966, p. 31-32. Hereafter cited as "Census, 1963: Industry Series".

[227] "Current Analysis", Section 3, p. 015.

SUMMARY OF MATERIALS CONSUMED BY KIND

| SIC CODE | CATEGORY | 1967 Delivered Cost (million dollars) | 1967 Percent of Total Less n.s.k.* | 1963 Delivered Cost (million dollars) | 1963 Percent of Total Less n.s.k. | 1958 Delivered Cost (million dollars) | 1958 Percent of Total Less n.s.k. |
|---|---|---|---|---|---|---|---|
| | Total material, parts, etc. | 1,768.1 | | 847.0 | | 469.0 | |
| | Not specified by kind (n.s.k.) | 29.5 | | 24.3 | | 5.0 | |
| | Total material less (n.s.k.) | 1,738.6 | 100 | 822.7 | 100 | 464.0 | 100 |
| 35710 | Special parts | | | 391.0 | 48 | 213.0 | 46 |
| 357330 | Special parts | 688.7 | 39 | -- | | -- | |
| 367408 | Solid state semi-conductors | 141.4 | 8 | 100.8 | 12 | Not available | |

*n.s.k.: not specified by kind

Table VIII

the 1960's to meet the demand which resulted from an imbalance of CPU and peripheral equipment growth; many of the independent peripheral firms found it necessary to spend ten per cent of sales on research and development during this period in order to compete with the well-financed main-frame manufacturers, and allegedly leading to technical advances and lower prices.[228] According to the U. S. Industrial Outlook 1970 of the Department of Commerce,

"Memories comprise the largest share of the total peripheral market with estimated shipments of over $1 billion in 1969. Other large segments include input devices, output devices, magnetic tape transports, terminals, and data transmission equipment. Rapid growth in the latter two areas reflects the burgeoning expansion of the data communications industry, which is closely allied to the computer and peripheral equipment industry."[229]

The importance of technological development of memories with the resulting gains in speeds and relative reductions in cost was recently summarized in a technical keynote presentation by Dr. C. J. Walter and A. B. Walter before the proceedings sponsored by Informatics Inc. Their findings are presented in Table IX, and are considered to be state-of-the-art, 1968. Some of the 1970 fourth generation announcements are beginning to provide additional information to Table IX technology data. Articles in the October

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[228] McLaughlin, R. A., "IBM's 370/145 Uncovered", Datamation, October 1, 1970, pp. 30-31; and "Antitrust: U. S. vs. IBM", Newsweek, January 27, 1969, p. 79; and "The IBM Program for Shaking Off Suits", Business Week, June 14, 1969, p. 49.

[229] "Antitrust: U. S. vs. IBM", p. 79.

SUMMARY OF MEMORY TECHNOLOGY THROUGH 1968

| TYPE | PREDOMINANT TECHNOLOGY | CYCLE OR ACCESS TIME | COST PER BIT RANGE |
|---|---|---|---|
| Registers and discrete bit storage | Monolithic integrated circuits | 50 to 500 nanoseconds | $1 to $10 |
| High speed control and scratch pads | Planar thin films | 100 to 500 nanoseconds | $0.50 to $2.00 |
| High speed internal main memories | Magnetic core | 0.3 to 5 microseconds | $0.01 to $0.020 |
| Random access auxiliary storage | Magnetic core | 2 to 10 microseconds | $0.01 to $0.15 |
| On-Line auxiliary storage | Electromechanical disk files | 15 to 150 milliseconds | $0.01 to $0.02 |
| Off-Line auxiliary storage | Magnetic tape serial access | Serial | Less than $0.01 |

Table IX

and November, 1970 Datamation indicate that memory technology is still in the forefront of hardware development, and cache memory concepts of the System 360/85 and 360/195 and indeed the "barrel and slot" techniques of Control Data Corporation's latest third generation hardware, have not simply been refined and renamed. The IBM System 370/145 contains the first fully semiconductor main memory, and a disk file subsystem that operates without a separate controller. It is said to have internal operating speeds that are five to eleven times faster than the 360/40 and 360/30; and a data transfer rate of up to five megabytes, which makes the 370/145 about six times faster than the popular 360/40 on input/output transfer. It must therefore be about twice as fast as the 360/50 by IBM's prior announcements. Datamation's comparisons are presented in Table X for these technological and price announcements.[230] It is emphasized that these data are from the early stages of new hardware announcements, and later the vigorous advertising and marketing tactics will present further cautions.

c. Patents

Patent infringements are relatively infrequent in the computer industry, however the expensive task in policing a very large number of patents together with the

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[230] "RCA's New Line: Just Enough to Check Migration to 370?" Datamation, October 1, 1970, pp. 47-48; hereafter cited as "RCA's New Line"; see also "Perspective: Leasing Firms", Datamation, October 15, 1970, p. 31.

SAMPLE OF FOURTH GENERATION MEMORY IMPROVEMENTS

| | 360/40 | 370/145 | 360/50 | 370/155 |
|---|---|---|---|---|
| **CPU** | | | | |
| cycle time | 625 nsec | 202.5 - 315 nsec | 500 nsec | 115 nsec |
| word size | 16 bits | 32 bits | 32 bits | 32/64 bits |
| arithmetic | fixed (16-bit) floating decimal (16- or 32-bit) | fixed (32-bit) floating decimal (32- or 64-bit) | fixed (32-bit) floating decimal (32- or 64-bit) | fixed (32-bit) floating decimal (32-,64-, or 128-bit) |
| registers | 16 general purpose | 16 gen. 4 cpu status | 16 gen. purpose | 16 GP. 4 cpu status |
| **MEMORY** | | | | |
| buffer cycle time | N/A | N/A | N/A | 115 nsec |
| buffer size | N/A | N/A | N/A | 8000 bytes |
| main memory cycle | 2.5 usec (2 bytes) | 607.5 nsec store (4 bytes)* 540 nsec access | 2 usec (4 bytes) | 2.1 usec (8 bytes) |
| main memory size | 16 KB - 256 KB | 112 KB - 512 KB | 64 KB - 512 KB | 256 KB - 2 MB |
| **I/O** | | | | |
| number of channels | 2 | 2 - 5 | 3 | 3 - 6 |
| aggregate data rate | 800 KB/sec. | 5 MB/sec | 1 MB/sec | 5.8 MB/sec. |
| **PRICE** | | | | |
| "typical" rent (purchase) | $19,350 ($873,000) | $23,330 ($1,110,000) | $29,100 ($1,370,000) | $37,365 ($1,801,110) |

* 8 bytes for instructions

Table X

large specialized staff necessary to determine the infringement of and prosecution of violations of patents contributes to the apparent absence of activity. Some of the leading cases will be discussed in a later section, however patent litigation has not been significant. Numerous journalists have alluded to the wholesale copying of ideas from time to time among the leading manufacturers.

The subject of patents in software has become an interesting challenge over the last two years for the U. S. Patent Office, which has refused to grant patents for software programs. The U. S. Court of Customs and Patent Appeals has reversed two rejections to date, and the Patent Office plans to continue the legal battle.[231] The court's first decision, on November 20, 1968, found in favor of Prater and Wei; and the most recent decision, on October 8, 1970 found in favor of A. W. Musgrave. In response to the U. S. Patent Office's contention that the program for seismic data correction method was unpatentable because it involved mental processes, the court said:

> "....all that is necessary, in our view, to make a sequence of operational steps a single 'statutory process' within 35-USC-101 is that it be in the technological arts so as to be in consonance with the Constitutional purpose to promote the progress of 'useful arts.'[232]

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[231] Hirsch, Phil, "Washington Review and Forecast", Datamation, January 1970, p. 99; and "Look Ahead", Datamation, November 15, 1970, pp. 17-18; and numerous reports over the period such as: "Rehearing Set in Computer Case", The Wall Street Journal, January 16, 1969, page 40, col. 3.

[232] "Look Ahead," Datamation, November 15, 1970, p. 17.

The Patent Office is justifiably concerned with the potential flood of patents, and an almost insurmountable task of unscrambling possible infringements. An equally serious threat to the hardware manufacturers exists should the above decision remain firm, because software firms are eager to compete with the systems software of the main-frame manufacturers. The 1969 suit of IBM by Applied Data Research, a leading software firm, has recently been settled privately, between the two contenders. In the original suit, however, Applied Data Research (ADR) claimed damages in the amount of $97.5 million in the IBM software package market, $10 million in custom services and software market, $10 million in the data processing services market, and 689 thousand dollars it had to pay IBM for software and services which it could have performed itself except for the nonexistence of separate pricing of hardware and software at that time. The out-of-court settlement with IBM was reported to involve about $1.4 million in cash to ADR and about $600 thousand in future revenue for services on ADR's Autoflow program.[233]

It is not possible to document the full significance of the granting of patents for software. The hardware manufacturers will be able to move more of the systems control techniques within the hardware, and the converse of that possibility was alleged in two of the now-settled suits

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[233] Pantages, Angeline, "IBM's Vigorous Defense Speaks Thin, as ADR Files #4," Datamation, June 1969, p. 121-123. See Section IV for full discussion of public policy issues; hereafter cited as "Thin Defense."

against IBM, namely that manipulative techniques were being guarded by patents when in fact the technique was accomplished by software. The movement of other control techniques within the hardware has appeared in the IBM 370/145, such as the integrated file adaptor (IFA) built within the CPU and substitutes for a controller for the new 2319 disk memory system.[234]

It is appropriate in the consideration of technology and patents and the effect upon supply and demand for a product, to acknowledge the lively discussion among scholars over the past several years. Considerable insight into protective patents and the impetus to innovation has been provided by Professor Harold Demsetz, Dr. Kenneth J. Arrow, Aaron Director of the University of Chicago Law School, John S. McGee of Duke University and B. S. Yamey of the London School of Economics.

Professor Arrow's simple analytical model led him to conclude that the "inventors' incentive under competition... will... always exceed the monopolist's incentive."[235] An opposite conclusion was reached by Professor Demsetz in a modified model that in the "linear model of two industries of

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[234] McLaughlin, p. 47-48.

[235] Arrow, Kenneth J., "Economic Welfare and the Allocation of Resources for Invention, in the Rate and Direction of Inventive Activity," National Bureau of Economic Research, 1962, p. 609, 621; and review and comment by Yamey, B. S., "Monopoly, Competition, and the Incentive to Invent: A Comment", The Journal of Law and Economics, October 1969, p. 235.

equal output size, the more monopolistic will give the greater encouragement to invention... the development of a monopoly invention... will receive greater rewards from a buying industry that is a monopoly."[236] Demsetz allows for the output restricting effect of monopoly and demonstrates that the incentive to invent is greater in a monopoly. To accomplish this result, the monopolist's cost for the invention is viewed as a fixed, lump-sum payment regardless of output, so that the monopolist's marginal cost curve is not affected. Thus his analysis described a bilateral monopoly with a lump-sum payment. Member firms of the computer industry would seem to regard within that lump-sum payment, an opportunity-cost foregone to prosecute or otherwise police the patent rights, and instead, apply additional funds toward research and development to reap new rewards from continued innovations. This seems particularly feasible in view of the time span of a patent, seventeen years, against the average computer generation of five years. Further, the time required to obtain a patent from application to issue approaches the five year life cycle of computer generations. Although Demsetz' model allows for monopsony, and therefore does not exactly describe the computer industry's customers (although

[236] Demsetz, Harold, "Information and Efficiency: Another Viewpoint," Journal of Law and Economics, October 1969, p. 19; and Yamey, B. S., op cit; see also Kamien, Morton I. and Schwartz, Nancy L., "Market Structure, Elasticity of Demand, and Incentive to Invent," The Journal of Law and Economics, October 1969.

they are relatively few and have a commonality of capital capacity), the computer industry has been described as near monopoly by Professor Scherer.[237]

The bilateral monopoly entails uncertainty and negotiation in the pricing process which further affects the degree of risk to the inventor. Professor Yamey finds that an inventor's risk may be greater than in the competitive situation when the negotiating or bargaining takes place after the inventor has committed resources to an invention. Such a situation opens the inventor to exploitation, which could be minimized only by the impractical method of negotiating prior to making any substantial resource commitment toward the invention. In the computer industry, this would require large capitalization in order to support the extensive research effort to develop (in advance) and test computers and components. Texas Instruments provides an example of a firm which has placed heavy amounts of research and development funds toward component development for its computer manufacturing clients, and as previously noted has found itself in competition with its clients, in the component making business. Its reaction is the opposite of what Professor Yamey would expect (lessening of competition due to an increase in risk), since it is reported that Texas Instruments, which already makes some small computers, plans to seriously enter the computer manufacturing industry.[238]

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[237] Scherer, p. 60.

[238] "TI Tilts at IBM's Market," p. 80; also see Yamey, p. 254.

Professor Yamey's discussion of Arrow's analysis is none the less enlightening in respect to the computer industry, specifically the assumption in Arrow's model that "only the monopoly (manufacturer) itself can invent".[239] It is widely viewed in the business and economic literature that in the computer industry, the dominant firm (IBM) has provided leadership in the marketing of computers and related services more so than in technology. This contention will be examined separately in sections on non-price rivalry and performance, but it can be noted that competition for innovation has apparently been sufficient for the industry to accomodate as many as 134 firms according to the Department of Commerce's 1967 Census of Manufactures, in SIC 3573.[240] This large number no doubt includes many small component and peripheral manufacturers, and the more frequently observed number is eight to ten firms which normally engage in the production of a full range or family of computers. Or, as Professor Hamid has noted in his dissertation on the computer industry, the largest eight firms account for 98% of the computer industry's output.[241] Table III listed ten firms and an eleventh category for the approximately one per cent measure of remaining output or installed equipment values.

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[239] Arrow, K. J., p. 619.

[240] "Census, 1967: Industry Series", p. 21-22, and "Special Report Series: Concentration Ratios in Manufacturing (MC67(S)-2.1) August 1970, p. 11-19, hereafter cited as "1967 Concentration Ratios".

[241] Hamid, Mohammed K., "Price and Output Decisions in the Computer Industry," Ph.D. Dissertation, University of Iowa, 1966, p. 32-35, 192.

The leading eight to ten firms in the computer industry have been found to actively compete to supply virtually all of the industry's output; the marketing of which has become the hallmark of IBM's success.[242] Apparent competition in technology to present the latest, fastest equipment has not been absent, and it can be maintained that the protection afforded by the patent has contributed to open entry above a fairly high capital requirement. Further, it would appear that the incentive to invent is quite active among differentiated products. However, it will be necessary to later examine the role of hyperactive promotion and market strategy in oligopolistic industries.

Space and time prevent an analysis of the very large number of patents which have been issued to the computer manufacturers in relation to their market share. Such analyses have occasionally been the modulus of congruence between resprective market shares and market power hypotheses resulting from industry studies. Professor Scherer studied the concentration of sales, patents, and research and development usage

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[242] Numerous business and marketing articles have acknowledged IBM's dominance, many of which listed the marketing genius as greater than the technological, until the evolution and perfection of the system 360 series in the 1960's. In addition to the historical development presented herein, some such references include:

Alt, Franz L., "Computers--Past and Future: The Costs of Computing and Failure in Computer Programs", Computers and Automation, January 1969, p. 14-16.

Schwartz, Lawrence E. and Heilborn, George H., "Marketing the Computer," Datamation, October 1967, p. 22; and

Trifari, John C. "High Time for Used Computer Bargain Hunters", Computer Decisions, July 1970, p. 10-13.

in a sample of 352 large corporations from among the Fortune 'top 500' for 1955 data. He found it essential to distinguish among different types of research activity and the degree of participation by private industry. He found that twenty per cent of all basic research in the United States in conducted by private industry; 65 per cent of all applied research, and 85 per cent of all development are likewise conducted by private industry. The first four firms in his sample accounted for 19.9% of sales, 9.7% of R & D employment, and 10.4% of all patents issued in a time adjusted period. The first eight firms followed a similar pattern: 27.5%, 16.4%, and 16.8%. Scherer concluded:

> "... the largest firms account for a considerably smaller share of both R & D employment (reflecting inventive and innovative inputs) and patents (reflecting technical output) than their share of sales.
>
> The weight of available quantitative evidence favors a conclusion that among the largest 500 or so U. S. industrial corporations, increases in size do not as a rule contribute positively to the intensification of R & D inputs or inventive outputs, and in more cases than not, giant scale has a slight to moderate stultifying effect. The most technically progressive American firms appear, with the possible exception of chemicals and petroleum producers, to be those with sales of less than $200 million at 1955 price levels."[243]

d. Product Durability

Until recently, there has been little evidence of the mechanical durability of computers, and the five year computer generation cycle does little to unveil the true longevity.

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[243] Scherer, Frederic M., "Firm Size and Patented Innovations," American Economic Review, December, 1965, p. 1104; and Industrial Market Structure and Economic Performance, p. 360-361; see also "Tiny Computers Lead a Price Decline," Business Week, May 11, 1968, p. 108. Scherer's article hereafter cited as "Firm Size," while his book will continue to be cited by author's name only.

The very recent growth of the used computer market may be the first market generated evidence of product durability. It is observed that the literature alludes that computer obsolescence is systematically programmed for a period of time sufficient to enable the leading firm to recover development costs.[244] At that point a new generation or family of hardware will have been readied for intense marketing. One result is the forced obsolescence of otherwise durable equipment into early retirement, or more recently into the quietly expanding used computer market.[245] The financial and economic considerations surrounding the individual firm's decision to procure used hardware is no less complicated than the original decision to lease, rent or buy new or current generation equipment. Indeed, the decision has become somewhat more complicated because of unbundling of software services, and considerations of maintenance, investment tax credit, and compatibility with other installed hardware. Heilborn reported that as the life cycle of a given system progresses, CPU's decrease in value more rapidly, with complete systems next, and peripheral equipment holds closest to its original value over time.[246] There is a strong element of overall demand for peripheral equipment in these observations, even though durability is indicated by information in these early reports of a growing segment of the computer industry.

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[244] Heilborn, George H., "Used Computers," Datamation, October 1, 1970, p. 22; "RCA's New Line," p. 47; and Trifari, J. C., p. 10-11.

[245] Ibid.; see also "Under IBM's Umbrella," Forbes, July 15, 1968, p. 16.

[246] Heilborn, G. H., p. 23.

Some of the other factors which have engendered the used computer market also indicated that durability is not necessarily a continuation of the original design, but from a cost point of view, some older equipment can be feasibly dedicated to specific tasks. The used market is also encouraged by:

1. The expansion of some firms to larger systems with some remaining tasks within the capability of equipment available on the used market.

2. New customer firms, previously beyond the feasible cost-fringe of mechanization. This is also the first example of off-the-shelf supply capability, as opposed to the traditional made to order structure.

3. Investment credit considerations has altered the data processing manager's tax and cost alternatives, however it is expected to eventually stabilize the used equipment prices.[247]

4. The residual value of prior generation equipment has maintained a higher level than previously anticipated. An example discussed by George Heilborn was a three-year old IBM 360/40 which had sold recently (October 1970) for a range of 75% of the original IBM price.

5. Hardware costs and, hence, investment commitments, can be reduced by the purchase of used equipment, _ceteris paribus_, in the replacement of similar rented or leased equipment, if the using firm has determined that a

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[247] _Ibid._, p. 22.

particular application has a long term life with little or no expansion. Static payroll applications might be such an application, which could release other newer equipment for production expansion without more expensive upgrading. Savings in the annual cost of depreciation mitigate in favor of such a combination.

6. Personnel training costs may be significantly reduced when the decision to employ used equipment involves similar equipment to that already installed.[248]

Advantages indicated by product durability in the used computer must, of course, be evaluated in terms of available maintenance support, software services, and personnel and equipment compatibility. Recent tight money markets of 1969 and 1970 have caused many businessmen to review the used computer market prior to making the final choice in hardware changes or upgrading.[249]

e. Product Value

In the examination of the constraints and determinants bearing on the supply of computers, the value of the delivered product was found to have repercussions throughout the market structure. Product value affects barriers to entry, cost structures of producing firms, pricing behavior, and production efficiency. A high value for goods in process is found in the reports of some manufacturers, which in turn relfects the high component and labor costs. Finished goods

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[248] Ibid., p. 23.

[249] Ibid., p. 22; see also Nelson, F. Barry, "Used But Useful?", Datamation, October 1, 1970, p. 26-28.

inventories are negligible, simply because the high product value and relatively long production period dictate a type of product which is made to a customer's order rather than stocked. The shortage of peripheral equipment and resultant high demand has not appreciably altered the practice of made to order.[250] The planning and research time has been found to be a significant part of the eventual product value, in an industry wherein personnel salaries are predominately high, and production cycles extend from one to four years.[251] For example, the IBM System 360 models were announced on April 7, 1964, and were delivered between May 1965 and February 1966. The largest member of that family, the 360/195, while not part of the initial announcement, has nonetheless not yet made its first delivery. Keydata Corporation reported that first delivery is scheduled for February 1971.[252]

The long delivery time from announcement to the first actual installation has caused considerable controversey among competing firms, and is to be later examined in non-price rivalry and as part of some of the antitrust suits.

Although the principal interest of this study is a focus on the equipment manufacturers, a review of the nature of the product requires acknowledgement that IBM contends that its purpose is not to sell a product, but to provide a service which incidentally includes a product they manufacture.[253]

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250 Hamid, M. K., p. 103.

251 Ibid.

252 "Computer Industry to Hit $27 Billion in 1957," Computer Decisions, January 1970, p. 38, hereafter cited as "Computer Industry to Hit."

253 Schwartz and Heilborn, p. 22.

This becomes significantly clear when a firm (customer) considers the total cost of hardware and related services. Software services, maintenance, supplies, and a host of preliminary services and studies to plan and implement data processing activities are just some of the surrounding services frequently needed to enable the hardward.

A recent example of the extensive value direction which computer equipment can achieve in a very large system, is the Defense Department's World Wide Military Command and Control System (WIMMIX) which has also encountered a delay in the first increment for Fiscal Year 1971, of about $64 million. Datamation reported that this massive system will eventually include more than 35 large computer systems, and that the investment in equipment over the next two years will exceed $260 million. EDP Weekly reports similar cost estimates, with a total foreseeable cost of $500 million.[254]

An interesting requirement contained within the Request for Proposal (RFP) of the Defense Department for the WIMMIX, is that the specification tended to coincide with the IBM service over product contention. Each bidder was required to demonstrate a data management system (DMS) capability at benchmark time, which could be demonstrated to be operational at a later time.[255]

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[254] Hirsch, Phil, "Perspective: DOD Releases WIMMIX RFP as House Kills Funds for First Two Computers," Datamation, November 15, 1970, p. 77; hereafter cited as "Perspective: DOD"; see also "RFP's Go Out for WWMCCS", EDP Weekly, Vol. 11, No. 25, October 5, 1970, p. 3-4.

[255] Hirsch, Phil, "Perspective: DOD", p. 78.

f. Business Attitudes

Business attitudes as a factor of supply will not be laboriously examined. Much conjecture is possible in observing that as a young, progressive industry most of the techniques and skills in production were developed in the post-World War II era. The young and aggressive leaders and innovators who have been responsible for its rapid development, have been seen in the history of the industry to have developed a high degree of professionalism and entrepreneurship, and perhaps more individualism than cooperation. IBM has characterized a great amount of the current intra-industry attitudes. A business environment seems to include the very careful development of a master plan, and then the skillful and deliberate execution of that plan. Two articles in Fortune have been previously referred to as indicating some of the inner-bickerings at IBM during the development of the 360 family and the termination of some sizeable projects, such as the 8000 series. The rivalry in personalities is tolerated as long as production has been demonstrated.

g. Unionization

Perhaps no input subject of the computer industry has received as little attention in the literature as that of the labor unions. Nor is it particularly surprising, when the high degree of engineering skills required is considered, most of which are not normally represented by unions. It was previously noted that, when IBM elected to build a plant for the making of components, it designed as much automatic equipment as possible to reduce the labor density

before the plant ever got started. When set into production, it then quickly became one of the two or three leaders in the world production of semiconductors.

As recently as October 1970 the first union was reported to have organized about 1250 programmers in New York, which could have eventual effects throughout the industry. Under the presidency of Paul Notari, this new organization, the Association of Computer Programmers and Analysts, will expand toward an estimated programmers' nationwide group of 400,000. The experience with labor unions in the computer industry, to date, has not been one of work stoppage. The unique labor factor in computer manufacturing appears to be the small number of highly skilled designers and engineers, who have been in such limited numbers relative to the labor demand, that manufacturers are willing to pay above-average wages. In addition, these manufacturers have employed expensive automatic techniques to maintain as low a labor density as possible. Another factor from the unions' point of view, might simply be that with such a relatively small number of employees in the entire industry, organization of that class of worker is not attractive.

A review of the general statistics of the Department of Commerce in the Annual Survey of Manufactures, General Statistics, indicated that the computer industry, based upon all 178 establishments so categorized in the 1967 statistics, paid the above average payroll per employee of $8,124; and that the production worker was represented among total employees as 51 per cent. A cursory review of other industries

revealed thatproduction workers are usually 75% to 84% of the total work force.

It is also noted from the 1967 Census of Manufactures that only thirteen manufacturers in the computer industry employ more than 2,500; and of the 50,700 production workers in the industry, the top thirteen firms employ 23,200. The total number of employees of these thirteen firms was 53,500 of the total 98,800.[256] The 1967 statistics are the most recent available which indicate a spread among the members of the industry; however, the 1968 Annual Survey of Manufactures of the Department of Commerce indicates surprising growth from 98,900 to 106,800 total employees. One surprising factor of this growth is that over the same period, comparably sized industries, such as radio and television, and electrical test equipment manufacturers were actually experiencing a decrease in total employment. Some perspective will be obtained in a later section on performance efficiency, however the relative stability of employment has contributed to security market analyst's tendency to consider the computer industry relatively immune to business fluctuations. Recent personal interviews with one brokerage firm indicates that this tendency is being retarded.

The above figures from the Department of Commerce's 1967 census reports, could cause confusion without the realization that the numbers in no way reflect the total employment

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[256] "Census, 1967: Industry Series" p. 11, see also Chandler, Alfred D., "The Structure of American Industry in the Twentieth Century: A Historical Overview", Business History Review, Autumn 1969, p. 275-293; and for information concerning the unions, see "Computers: Out of the Slump", Newsweek, November 9, 1970, p. 79.

of the various computer manufacturers. The Fortune annual survey for 1970 reported that the fifth largest corporation among the top five hundred in sales, IBM, was also fifth in total number of employees: 258,662 at the end of 1969. While no precise explanation could be found, it is suggested that the latter number includes a number of persons engaged in one of the five other industries of IBM, as reported by Chandler using 2-digit classifications, or simply a variance between the international and domestic employees' census of IBM. The latter seems likely, since IBM's membership in the typewriter industry could account for a maximum of only 26,000 employees, according to the same Department of Commerce census.

2. Demand for Computers and Computation

Certainly the demand for computers is derived from the demand for computation, just as the demand for automobiles is derived from the demand for revolutions per minute, or miles per hour, or miles per gallon. Reasonable men have not concluded that the latter performance characteristics are interchangeable with the demand for (and sales of) automobiles. Only one recorded effort could be found that attempted to measure and display the demand for computers, that of Gregory Chow.[257] His analysis was the most complete available, and yet it too depends upon a selected representation of computer

[257] Chow, Gregory C., "Technological Change and the Demand for Computers," The American Economics Review, Vol. LVII, No. 5, December 1967, p. 1117.

characteristics to derive a demand curve. Invariably, most of the studies to date have retired to an analytical model, which purports to structure the demand for computation as a means of assessing the demand for computers. Yet many scholars in similar endeavors have noted that one must pursue a study along lines for which reliable data are available and for which some standard of accuracy can be maintained. The essential sole source of information on the number of computers of various configurations which have been shipped or installed, has been noted to be acknowledged by its publisher, International Data Corporation, as based on estimates in many instances. Yet, as a measure of demand, it may be no more inaccurate than some of the computational studies. Gregory Chow, for example, acknowledges that his analysis is subject to unknown errors resulting from the variations of programming efficiencies, which certainly can affect the speeds of instruction execution cycles or memory timing.

While this is not insurmountable confusion, it is clear that the computer industry is not represented in the literature and texts with respect to analyses of demand. Indeed, Chow's work is the only one available in the economic literature. Perhaps the data now available from the Department of Commerce will encourage such studies.

In the interim, if the performance approach can be used, and Chow's is more recent and complete than most, although he ascribes to only three characteristics,[258] then it

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[258] Ibid., p. 1120.

might also be feasible to interpret the results to specific families of computers. Perhaps then a discrete view of the demand curves for various sizes of computers will emerge; from this, the serious student would hope to be able to construct empirical representations of demand in the computer industry. Grosch's law may be useful to assist in the discrete segmenting of the existing power/cost studies of specific hardware, according to what has been actually produced at various prices and performance levels in the industry. The law of Herbert R. Grosch is suggested because it has been found somewhat indicative that average cost of computer equipment decreases substantially as size increases, in studies by Knight and Solomon, and as reviewed in Sharpe's, The Economics of Computers. Sharpe summarized Grosch's law as,[259]

$$C = K\sqrt{E} \text{ or } E = \left(\frac{1}{K^2}\right) C^2$$

where C = the cost of a computer system

E = the effectiveness (performance, speed, throughput) of the system, and

K = some constant.

In Sharpe's review of Chow's analysis, he concluded that the amount of computer power installed can be expected to triple, eventually, if the price remains constant. However, Sharpe maintains that prices will actually fall, not rise, negating the usefulness of Chow's approach. What each of them mean by the word "price" may bring them into closer

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[259] Sharpe, William F., p. 315.

agreement than Sharpe would imply, since Sharpe prefers to consider price as being relative to computational output. By this analogy, one might find that the price of automobiles has been decreasing over time, in view of the increasing performance in miles per hour.[260]

a. Demand in Computer Manufacturing

Demand and supply analyses along traditional paths of economic endeavor have been found to be not widely discussed in the professional literature. The numerous, virtually unlimited, array of tasks and computations, and the combinations of the many possible performance capabilities which can be designed in a computer system have without doubt prevented complete studies. The studies of Solomon, Knight, Chow, and Sharpe provide a starting point, even though at present they represent the output of a "typical" computer, not the output of the computer industry. Yet a count of cabinetry would add little to the understanding of demand and output. The comlexity grows when the peripheral combinations are considered and, as Chow has acknowledged, when software, and in particular the variabilities in performance from systems software, compiler and interpreter designs are added to the vast matrix of hardware configurations. The temptation to consider any analysis complete upon solving that one million calculations now cost an average of twenty-five cents, is puzzling, since the customer or user cannot relate that performance to an appropriate configuration of hardware.[261] Over the past

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[260] Ibid., p. 257-262.

[261] Alt, Franz L., p. 14.

several years, it has been frequently reported in the literature that many firms upon initial entry into a computerized operation have obtained the wrong computer capability, or that many users have considerable untapped capacity in their hardware. The large number of users with third generation hardware, who were yet employing second generation software programs through emulation, some for years after obtaining the third generation hardware, has likewise been reported in the literature frequently. The author has personally visited factories in New England where this result was witnessed. The billions of computations for twenty-five cents seems meaningless to under-employed hardware at a fixed price.

To the maximum extent possible, this section will not be devoted to the derivation of a new approach for the measurement of the number of bits or executions per dollar. The studies of Knight, Chow, Solomon and Sharpe were among the best available for the purpose of evaluating one aspect of performance; however, some use will be made of the techniques and results.[262] That Grosch's law is largely valid as a general expression of cost to power of output has considerable utility. It will first be necessary to identify some of the basic elements of demand from Figure 1.

b. Elasticity of Demand

The relative responsiveness of the quantity of computers in any given category to changes in prices has not been published, nor is it easily measured in view of the state

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[262] Chow, G. C., p. 1117-1130; see also Knight, K. E., "Fast" and "Performance", September 1966 and January 1968; and Solomon, M. B., "IBM", p. 435-440.

of industry statistics. The following basic conditions in the computer industry reflect the possible responsiveness.

(1) The rigidity of the price schedules of the dominant firm, and its high degree of price leadership obviate any noteworthy movement in the relationship of demand to prices.[263] It does not follow, however, that the "set price" condition is complete, for indeed, the product as conceptualized by that dominant firm includes a considerable package of service, within which price movement can more subtly effect demand.

(2) The complexities of the apparent price and the effect on demand from the surrounding services, present a dampening effect or slow movement of services' pricing. The true effects of unbundling of hardware and software are not yet documented, seventeen months after the dominant firm announced the separate pricing. Price leadership disintegrated as the followers reacted slowly, some (GE) even raised hardware prices; others (Burroughs) waited for a new generation. The customers simply kept paying whatever was to be charged.[264]

(3) The lack of reliable information on the quantities of computers shipped or installed, as a measure of response, complicate demand measurement.

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[263] ___"Tiny Computer Lead," Business Week, op. cit., p. 108; and Schwartz and Heilborn, p. 22; and Hamid, p. 143-149.

[264] ___"Computer Industry to Hit", p. 2; and "Computers: The Wide Open Market That IBM Unbundled", Business Week, May 2, 1970, p. 85-88.

(4) The customer of the computer industry is generally better informed, or thought to be, because that customer is normally a business organization with resources and talent to operate the hardware, and executives to manage its operation. Such commitment of scarce resources by an organization, flows through a decision process, which as Professor Hamid has found using the Cyert-March behavioral theory of the firm, results in an internally reactive customer to a full scale of qualitative and quantitative determinants. For example, response to a lower price announced by a peripheral manufacturer may be delayed until technical compatibility can be determined or because of contractual commitments of existing hardware.

(5) The present tools are insufficient to precisely measure elasticity; with output presently measured in bits or memory speed, the industry growth evaluated in total sales values or shipments' values, only the most general conclusions of price response can be advanced.

The present difficulty in the precise measurement of elasticity may not be critical to the understanding of an industry which deals in a complex capital good, sold to a sufficiently small number of informed customers that demand can almost be evaluated by interview as opposed to reactive curve-price-quantity plotting. Professor Hamid reported that the manufacturers which he surveyed, replied that they placed little reliance on demand forecasts, for example, and that price evaluation by customers placed more importance on prospective future prices than on past prices, or historical

pricing patterns.[265] Future studies, however will benefit from price comparisons with those on the used computer market, as previously noted.

The study of technical change and the demand for computers by Gregory Chow acknowledged the difficulty in estimating output elasticity. He employed a univariate measurement of technological change, from the demand side, by measuring price reduction effects in the computer industry between 1955-1965. His model was adjusted to 1960 dollars, and he used three hardware characteristics which he tested for relative representativeness: multiplication time, memory size, and access time. He assumed a high representation for these characteristics, but acknowledged that the omission of software as a determinant of improvement could lead to serious error.[266] Such is of course true for any of the studies previously examined involving the measurement of hardware output based on a representative sample. Nonetheless, Chow's study was the only one found which attempted to present a point estimate of the price elasticity of demand for computers, which he found to be 1.44,[267] in the long run. This result is presented as D* in Figure 2.

Chow asserts that two elements account for the increase in the use of computers, and he confirmed that the

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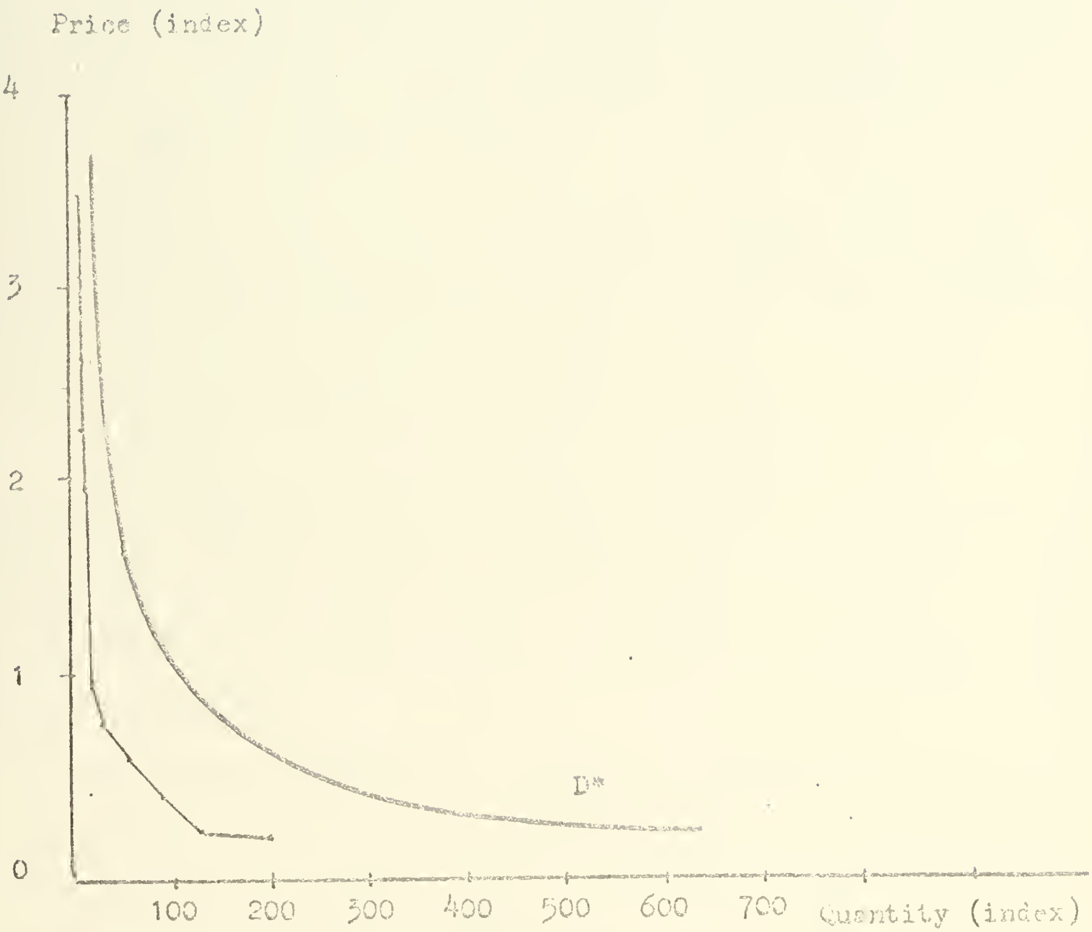
[265] Hamid, p. 140-146.

[266] Chow, G. C., p. 1117-1130.

[267] Ibid., p. 1126.

LONG RUN COMPUTER DEMAND CURVE




Chow's results showing the long-run demand curve, D*, with an elasticity of 1.44 (constant by assumption). Actual price-quantity pairs are represented on the inside curve.

Source: Chow, Gregory C., "Technological Change and the Demand for Computers," American Economic Review, December, 1967, p. 1117-1130, also published in Sharpe, W. F. The Economics of Computers, Columbia University Press, 1969, p. 337-352.

Figure 2

price per unit of output decreases over time. The first is simply the time required for a new product to reach an equilibrium level even without quality changes. The second occurs at the same time, and is the increase in quality of the product, and as the increase occurs, the equilibrium level is continuously raised. To quantify this from two popular differential equations which express natural growth, Chow elected to use the Gompertz curve, of the form:

$$\frac{dQ}{dt} = Q\ (\ln Q^* - \ln Q)$$

where the value of $Q^*$ is the equilibrium value of Q, which actual value (Q) approaches asymptotically. Sharpe restates this in the discrete time periods as:

$$\ln Q_t - \ln Q_{t-1} = (\ln Q^* - \ln Q_{t-1})$$

To apply the adjustment process of the Gompertz curve, Chow hypothesized that the price, in predicted monthly rental ($P^*$), increased with memory size and decreased as memory speed increased, as follows:

$$\ln P^* = a - b_1 \ln t_m + b_2 \ln M - b_3 \ln t_a$$

which is:

$$p^* = A \frac{M^{b_2}}{t_m^{b_1}\ t_a^{b_3}}$$

where $p^*$ = predicted monthly rental

$t_m$ = multiplication time (in microseconds)

$M$ = memory size (in thousands of bits)

$t_a$ = access time (in microseconds), and

$A = e^a$

Then assuming that price adequately predicted computing power, he applied the quantity of computing power of each system and its rental measurement based on adjusted 1960 prices, of the form:

$$\ln Q = -0.1045 - 0.0654 \ln t_m + 0.5793 \ln M - 0.1406 \ln t_a$$

He then calculated the price index based on actual IBM rental information, and adjusted these prices by deflating the "absolute" values to reflect changes in the general price levels. The price-quantity pairs could then be used to estimate a demand curve (D*) by regression, having the constant elasticity:

$$\ln Q = a + b \ln P \quad (Q = AP^b)$$

where $A = e^a$ and b = price elasticity of demand, less than zero.

The long run equilibrium demand curve, D*, expressed in Figure 2, may not exactly represent the actual price-quantity paired curve because the adjustment process represented by the Gompertz curve was relatively slow. The coefficient of the Gompertz equation was found to be 0.2526. When this coefficient is near zero, it represents no adjustment; when it is closer to unity it represents full adjustment in a single time period. Sharpe makes the point that if price remained constant over succeeding short time periods, as quantity demanded increased, a long run equilibrium value, Q*, would be eventually reached and would indicate the points for a demand curve. He stated that D* should not be represented by short run observations of prices and quantities, but rather, only by long run equilibrium positions. He

demonstrated the results, as indicated in Figure 2 by the inside curve, when future prices are held constant; it is the Gompertz curve with a coefficient of 0.2526. If, in fact, future prices fall and technology increases the power or performance, then Chow's representation based on constant prices will not reflect long run demand for computation. Sharpe then concluded that neither approach (Gompertz curve nor the Logistic, or S curve) is likely to satisfactorily predict growth in computing power.[268] Chow preferred the use of the Gompertz curve because of comparable empirical studies conducted by A. D. Bain concerning a similar early-growth, technology-oriented television industry in which the growth rate was found to be higher at an early stage and then found to decline gradually in later time periods; such was also the findings of Chow with respect to the computer industry.[269]

c. Rate of Growth of Demand.

The complexity in measuring the growth of demand for the use of computers in the United States follows from the same difficulties which were found to hinder the measurement of elasticity of demand, product value, costs, product durability and other input determinants. However, Chow observed that the 1960 based rental value for computers grew from $370 thousand per month at the end of 1954 to about $194

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[268] Sharpe, p. 358-361.

[269] _Ibid._, p. 1126.

million at the end of 1965, for an average annual rate of growth of 88%. In another study by Professors Schwartz and Heilborn[270] it is challenged that technological change should be isolated to present natural growth in the computer industry, and they observed that technological impetus is more pronounced in the early years of an innovative industry. (This confirms Chow's findings of a slightly earlier period.) Schwartz and Heilborn also provide an extremely interesting very long range projection of continued growth in the industry, which fully accomodates the somewhat shorter range projection of Chow in his selection of the Gompertz curve. These combined results are presented in Figure 3, and it is apparent that growth is quite pronounced in the early stages of development, gradually decreasing over time. These two studies represent the only available analysis which could be found concerning the rate of growth of demand for computers. The study of Schwartz and Heilborn contended that considerable misrepresentation had been made in the mid-1960's that the demand for computers had begun to mature, in terms of measurable growth rate. They also observed, contrary to most of the literature at that point, two directions of future growth:

(1) The rapid expansion toward the small computers

(2) The sharp reduction of growth in large scale equipment owing to delays in perfecting effective time-sharing and management information systems.[271]

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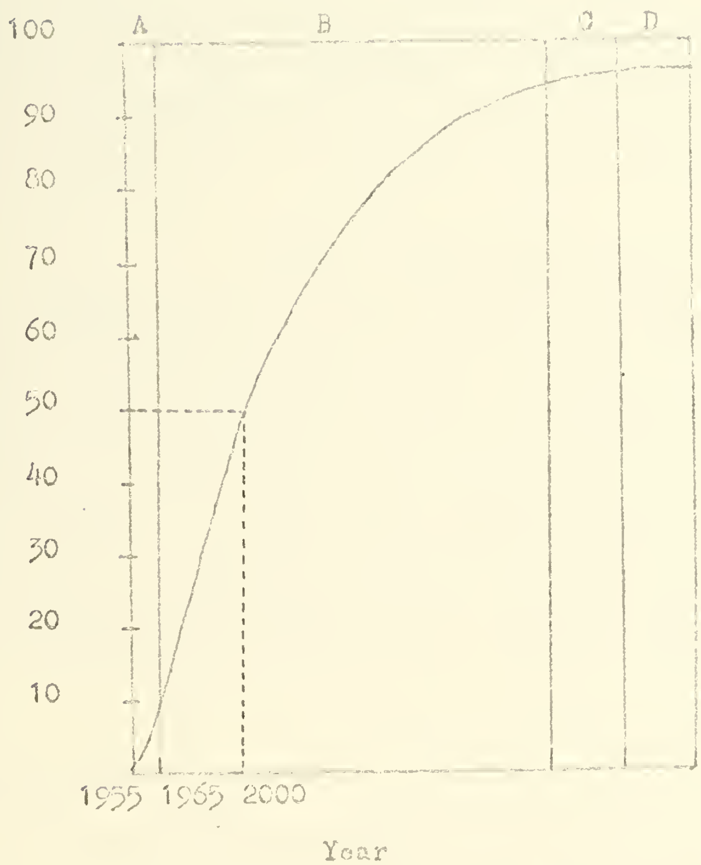
[270] Schwartz and Heilborn, p. 22.

[271] Ibid.

## LONG RUN COMPUTER MARKET

Cumulative dollar value of shipments
net of returned and scrapped machines
Percentage of market saturation




Source: EDP Industry and Market Report, January 15, 1966 as reported in Schwartz and Heilborn, "Marketing the Computer", *Datamation*, October, 1967, page 24.

Figure 3

These projections appear to be well supported by current developments, including the yet unresolved difficulties in the communications interface task, which will hold the utility concept well into the future. Schwartz and Heilborn also projected a slowing of the five year interval between computer generations as part of a long range tempering of technological growth, but the announcements of 1970 may have delayed that prediction.

In explanation of the use of the S-shaped or sigmoid curve they relate that economic theory holds that the rate of growth of demand depends on both the present size of the market and the difference between that value and some hypothesized saturation level. Further explaining the results presented in Figure 3:

> "... it fits quite well the observed behavior of many markets over time. In section A of (Figure 3), demand grows exponentially in the period after the introduction of computers, because potential customers want the product badly. Section B shows that the rate of growth gradually declines until absolute year-to-year growth becomes stationary as initial demand for the computer are satisfied. Demand falls as more and more capital in the form of computers is added to fixed amounts of labor and natural resources, so that the profitability of investing in additional equipment falls. In section C, the absolute rate of growth declines because the profitability of investing in new machines is still falling and existing computers, being long-lived, need not be replaced."[272]

Section D of Figure 3 represents the accomplishment of saturation, at which time demand for computers is projected to be for replacements and upgrading.

In a recent shorter range projection, the Diebold Group also accounted for the small computer growth. Figure 4

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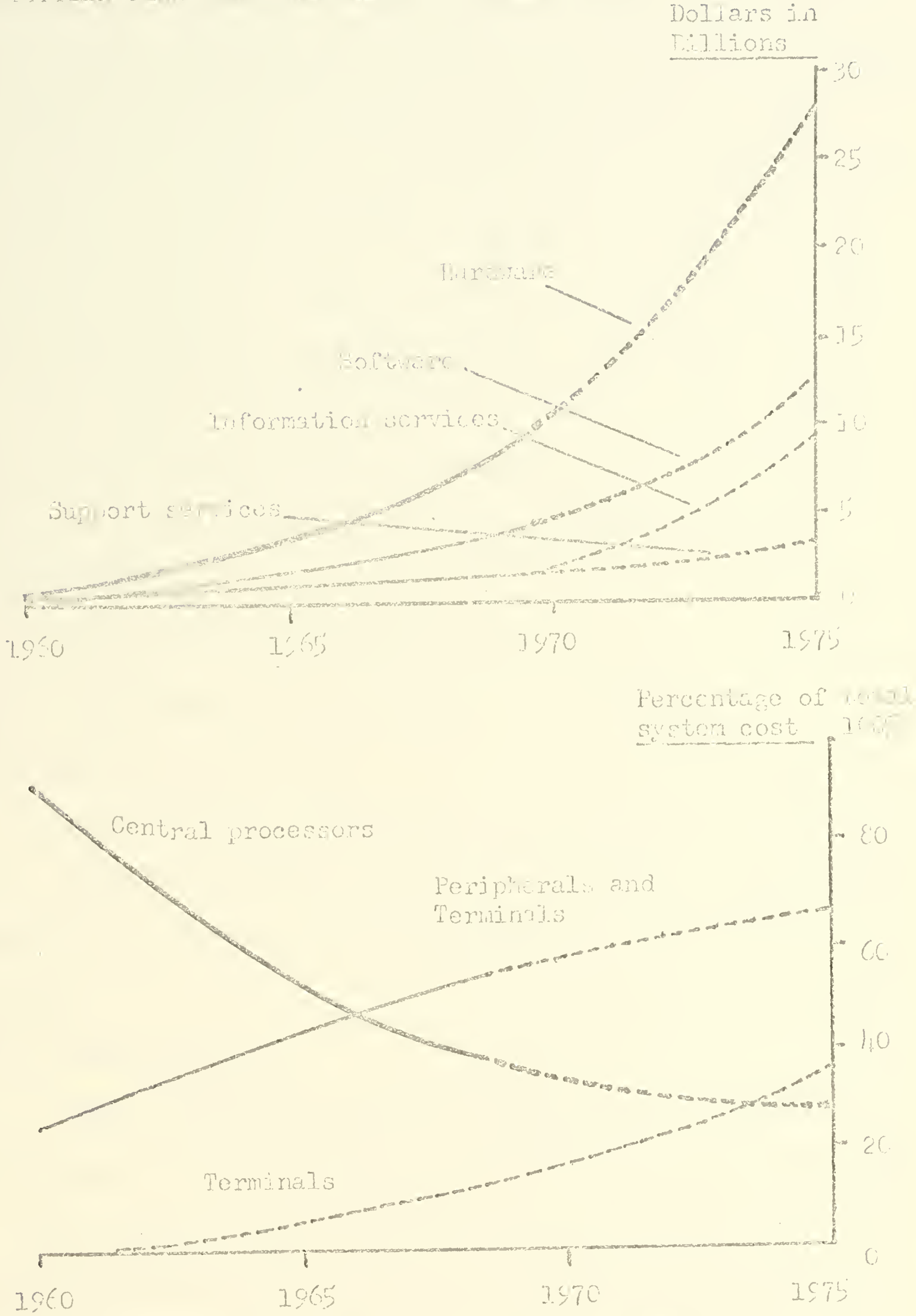
[272] Ibid., p. 24.

FIFTEEN YEAR HARDWARE GROWTH AND PROJECTION




Source: Computer Decisions, Vol. 2, No. 1, January 1970, p. 2.

Figure 4

summarizes their findings as reported in Computer Decisions, and it can be noted that the accelerated growth for peripheral equipment is projected to 1975. Diebold expected that the number of computer systems will reach 46,000 by 1975, and that 37,000 of them will be the small, mini-computer; of that amount, 22,000 are expected to be employed in dedicated control of production equipment.[273] Somewhat contrary to the Schwartz study, however, Diebold projected that a new information services industry (through remote terminals) will emerge, with a value of $6.4 billion (sic) by 1975. They further note that this growth is largely attributed to the aerospace industry experience in extensive applications, which included:[274]

(1) Computer-aided design

(2) Design applications in archetecture, animation, and city planning

(3) Interactive graphic display applications

(4) Procurement tasks such as vendor selection, bid evaluation, purchase order preparation, and material flow control.

d. Substitutes

The subject of the availability of substitutes and cross elasticity of demand at various prices reopens the complex issue of the determination of a cost-benefit relationship among alternative choices of information processing

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[273] ___"Computer Industry to Hit", p. 2.

[274] Ibid.

(including manual), and the cost trade-offs which have made comparisons particularly difficult. Simple cost displacement methods have been attempted by customer firms with limited success.[275] In most matured applications, the choice between automated and non-automated techniques has no longer been open to complete reversal except when sizeable reorganization and cost benefits can be clearly demonstrated. Personnel adjustments and training investments likewise bear heavily on alternatives involving substitutes.

J. M. Clark has argued persuasively, in general, that long run demand schedules might "in numerous cases approach the horizontal so closely that the slope would not be a matter of material moment, in light of all the uncertainties involved."[276] This hypothesis has had important performance implications which will be examined in a concluding section. The demand for products, or as IBM asserts, for services, of a firm or an interacting group of firms which possess market power is much more price elastic over the long run than in the short run. Two reasons have been proposed for this by Scherer.[277] The first is that competition among products or services is much more intense in the long run than over any observable short period. It takes producers and consumers time to evaluate and react to product

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[275] Alt, F. L., p. 14-16.

[276] Clark, J. M., "Toward a Concept of Workable Competition", The American Economic Review, June, 1940, p. 248.

[277] Scherer, F. M., p. 213; and Schwartz and Heilborn, p. 22.

changes in spite of active marketing pressures. The second is common to most industries with even a semblance of competition, in that a price policy which has maintained prices persistently above average cost levels, may attract new entry into the industry. The very simple mechanism over time from the above condition, is that if such new entry competes to a point of reducing the price levels, some individual firm's average cost might be found in a loss condition. Entry and exit effects of substitute products in the computer industry, with its carefully differentiated hardware, is particularly difficult to evaluate since leading manufacturers are willing to endure great development losses. Proper evaluation of the cross elasticity of substitution in the computer markets is an ambitious area for analysis not yet possessing data for such analysis. The complexities of the hardware and related software choices and the uncertainties of technology, together with the period of contractual commitment have served to slow the reaction time of the using firms. At the risk of over-generalization, it would appear in the dominated computer market that the effects of substitution have been minor, although not necessarily non-existent. As noted previously, the emergence of the used computer market, as a new price-substitute factor in the new computer market, may be the first opportunity to measure the effects of substitution.

e. Marketing and Hardware Acquisition

The scope of marketing in this context does not include advertising and customer engineering services. Some of the effects of these very broad areas and the relation to

hardware manufacturing will be necessary. The practice of buying and selling of computer hardware has been observed to involve a very detailed manufacturer's "list price schedule" rather than solicited, sealed-bid price derivation. Nor is such a practice uncommon in markets involving industrial products. The many decision steps leading to a list price schedule on the part of the manufacturer, and the steps to be followed on the part of the purchaser, were studied by Professor Hamid following the Cyert-March behavioral theory of the firm.[278] He found the computer industry to be highly adaptive to that approach because it focused on the full range of steps or considerations, not all of which are, or can be quantified. He found manufacturers interacting in the price leader technology oriented industry; and he found many levels of buyer and seller interaction to arrive at complex hardware and pricing arrangements.

There is a considerable volume of literature which has defended or attacked the profit maximization hypothesis of the traditional firm theory, but at the operating level of the businessman in the computer market, there is an environment of dynamic uncertainty ranging from potential technological obsolescence to application success. The user, even as a businessman, is faced with the skillfull marketing engineer on the one hand, and his own internal firm complexities which sometimes seem to be in conflict with ultimate firm's goals.[279] Very generally, the argument centers

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[278] Hamid, M. K., Chapters II, VII, and VIII; and p. 192.

[279] Scherer, F. M., p. 27.

around the traditional firm theory as having been designed to explain "... the way in which the price system functions as a mechanism for allocating resources among markets; relatively little is said about resource allocation within the firm."[280] The behavioral theory has considerable intuitive appeal in that it attempts to identify price as a fact in the decision process. Cohen and Cyert dismiss profit maximization of the conventional theory of the firm, and then outline five goals of the behavioral model:[281]

(1) Production goals

(2) Inventory

(3) Sales goal

(4) Market share goal

(5) Profit goal

Dr. Hamid appears to finally acknowledge the profit goal as important in his report of the results of a survey of eight manufacturers of computers (three did not respond) and five related firms. Profit, growth, reputation, and return on investment were ranked highest by the respondents.[282]

The traditional theory of the firm does not appear to provide any unusual difficulty in explaining the operation of the oligopolistic market behavior which Dr. Hamid and others have observed in the computer industry. All of the

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[280] Hamid, M. K., Chapter IV; see also Cohen, Kolman, J. and Cyert, Richard M., Theory of the Firm: Resource Allocation in a Market Economy, Prentice-Hall, 1965, p. 330-331.

[281] Cohen and Cyert; p. 336-337.

[282] Hamid, M. K., p. 195.

many elements of price and output decision-making can be observed along the lines of the market mechanism, whether a dominant firm affects the market or is dominated by market conditions. The difficulty in evaluating some of the economic effects in the industry is the absence of reliable relevant data, rather than by a choice of models to afix such information. The many cost decisions which the leading manufacturers surely engage, are not disclosed for public scrutiny. The public interest might thereby be indirectly hampered if unreasonable profit maximization has been permitted; this possibility will be examined in the section on public policy.

f. Cyclical Character of Demand

The constant need for larger, faster memory handling seems to be the response of technology (supply) to demand. Yet computer generations which have ushered the technology are also within the control of the manufacturers. The possibility of planned obsolescence has been explored in the literature at length,[283] and the question of whether technology will continue to punctuate succeeding generations has been raised by Schwartz and Heilborn. The pattern of a generation cycle has become a part of the structure of the market which seems likely to continue, not only as a means of introducing advanced capability and timing of the research

[283] Heilborn, p. 22-25; Nelson, "Used but Useful", p. 26-28; and Alexander, T., p. 126-129.

effort to the market place, but an economic necessity of cost recovery for the manufacturers. That capital intense production and research commitment in the computer industry has become a pattern with no apparent alternatives, is beginning to become an economic reality.

## B. MARKET STRUCTURE AND MARKET MECHANISM

The electronic digital computer industry requires four divisions to permit its essential product to function: hardware, software, services, and supplies. Several other categorizations might include important divisions such as training and systems' studies. The focus of this study has been placed on the equipment, or hardware, manufacturers which frequently required an understanding of those other divisions in order to comprehend the existing market structure. The importance of the market structure in determining the behavior of the firms in the industry, and likewise the industry's contribution toward major economic goals, which is the performance objective will now be examined. The causal flow of the active elements considered in the basic objectives of supply and demand (Figure 1) provides the foundation for this structure.

### 1. Oligopolistic Structure

Although the Department of Commerce reports examined in the basic conditions listed as many as 140 to 178 firms in the computer industry classification (SIC 3573), it has also been determined that 98% of the output of the industry in terms of sales value of shipments can be attributed to as

few as eight or ten manufacturers. Table III listed the most recent information available concerning the sales of the ten leading firms, and supports the oligopoly definition ascribed by Drs. Hamid, Schwartz, and Heilborn. In a classic study of oligopoly and antitrust by Kaysen and Turner, the definition of an oligopoly was found to center around the percentage of the industry's sales attributed to each of a small number of firms.[284] This definition will become more complex in the consideration of market conduct, for, as Richard Caves had stated in his text on American Industry, the interaction of sellers in an oligopolistic market is not only a distinguishing feature, it affects behavior and ultimately performance. Caves refers to this as mutual interdependence.[285]

In an extensive study by Kaysen and Turner, 27 industry groups were divided into three categories, which have become constants of reference in the economic literature: Type I oligopolies, in which the eight leading firms (in sales) account for at least 50% of the industry sales; Type II oligopolies in which the leading eight firms accounted for between 33 and 49%, and the top twenty accounted for at least 75% of the industry's sales; and "unconcentrated" industries with many firms and lower concentration ratios. The general conclusion of Kaysen and Turner is summarized in Table XI:[286]

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[284]Kaysen, Carl and Turner, Donald F., <u>Antitrust Policy</u>, Harvard University Press, 1959, p. 21-41.

[285]Caves, R., <u>op</u>. <u>cit</u>., p. 39.

[286]Kaysen and Turner, especially Tables of Statistics, appendix, p. 275-291; and Scherer's summary, p. 60-61.

THE NUMBER OF OLIGOPOLISTIC INDUSTRIES

| | Number of Industries | Percentage of Total 1954 Sales |
|---|---|---|
| Type I Oligopoly | 64 | 23 |
| Type II Oligopoly | 56 | 36 |
| Unconcentrated | 71 | 41 |

Table XI

From this very broad study, and numerous other sources, it is readily concluded that the computer industry satisfies the Type I oligopoly. Not only the top eight firms, but indeed the top firm has accounted for not 50% but 69 to 73% over several years. Table III has indicated that the top ten firms account for 98.9% of 1969 computer industry shipments. Professor Scherer listed the computer industry among leading examples over the past several years which have approached monopoly, when, in 1968, IBM managed "to retain more than 70 per cent of the turbulent digitalelectronic computer and data processing equipment market."[287]

Although such studies normally concern sales, the data concerning value of shipments has been necessary to provide a denominator of sales and rentals of computer equipment. It also contributed to more refinement in that sales figures of manufacturers frequently included revenues from non-equipment oriented production. The unusual difficulty

[287] Scherer, p. 60.

in determining accurate industry data has been noted; many common sources of such data to businessmen were traced to a single leading source: International Data Corporation, or its industry newsletter EDP Industry and Market Report, both of Newtonville, Massachusetts. Adams Computer Characteristics, or its successor, Keydata, Computer Characteristics Review of nearby Watertown, Massachusetts, are also referred to in the literature as data sources. The latter quarterly summarizes hardware characteristics, and lists general price ranges, but does not attempt to record installed quantities.[288]

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[288] Numerous common business, economic, and marketing publications refer to these two sources or newsletters thereof. For example, Computerworld is a weekly industry statistical report of International Data Corporation (their use of an address of both Newton and Newtonville, Mass. with identical street addresses has not been resolved). Keydata, as noted does not publish quantities of computers shipped. Thus, the bimonthly EDP Industry and Market Report was found to be the only source for such information, and since the leading firms in the reports refused to divulge exact data, the information is derived from customer surveys. By telephone conversation with Joan Schaar, of that industry publication, it was learned that this survey procedure, called the "Blue Sheet", is regularly mailed to all known computer users and manufacturers. Common sources such as Barrons, The Wall Street Journal, Business Week, Forbes, Standard and Poors, Computers and Automation (which has same Newtonville address), and indeed many of the statistical reports listed and cited herein, all have depended directly or indirectly on this single source. Since the Department of Commerce is forbidden by law to disclose industrial firms' data, the sole source of census information becomes: International Data Corporation. That such data may be highly accurate is not questioned. EDP I & MR discontinued estimating its own accuracy; however, the survey to user firms was estimated to include 80% of the industry in March 1967. EDP Industry and Market Report, March 15, 1967, p. 10.

The Department of Commerce conducts a census of manufacturers approximately every five years. The published reports therefrom, which typically take one to five years to compile and publish, provide information concerning the employment, manhours, payrolls, value added by the manufacturing process, capital expenditures, cost of materials, inventory data, and value of products shipped, all classified by numerically coded industry groups. Current legislation provided that such census undertaking shall be conducted in years ending in "2" and "7", hence the next census of manufacturers will be conducted in 1973 covering activity which will have occurred in 1972.[289]

The classification index used for these census is the Standard Industrial Classification Manual (SIC), which presents industrial activity in a heirarchial system by major industries. The 1967 census has been published between June and November 1970 (preliminary reports were published about one year earlier). That current census lists twenty-one 2-digit major manufacturing industry groups, 150 subdivisions of 3-digit groups, which are further divided into 422 4-digit industry and product groups, 1200 5-digit product classes, and finally, about 10,000 7-digit individual product types. Not all industrial input into the industries surveyed is delineated in the latter category; rather, as a means of developing industrial activity apart from that which might

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289 ___"Census, 1967: Industry Series", p. iv.

be visibly represented by any given firm, deeper and deeper classification becomes necessary. This "SIC" system for U. S. industrial classification is portrayed in Table XII for the computer industry, and is representative of much of the other industry's formats. The SIC code followed by an asterisk indicate a digit-level category in use for the computer industry prior to the final report series for 1967.[290]

The Department of Commerce also prepares a special report series as part of the census, which includes information on the degree of concentration in any given industry group, usually according to the 4-digit classification. The computer industry was found to require deviation from the normal reporting method of value of shipments accounted for by the 4, 8, 20, and 50 largest companies. Instead, the computer industry is reported by "value added by manufacture", ostensibly because value of shipments contains a substantial and unmeasurable amount of duplication. Intra-firm transfers of course would diminish the usefulness of such data. The value added method presents a less concentrated picture for the computer industry than the market share evaluation implicit in Table III data. The total value added for SIC 3573 was $1,926.4 million and the percentage attributed by the standard grouping of the 134 firms, in the order 4, 8, 20, and 50 largest companies, was: 66%, 83%, 92%, and 98% respectively.[291]

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[290] Ibid.; see also "Census, 1967: Summary Series," and Singer, E. M., Antitrust Economics, Prentice-Hall, 1968, p. 160-168; and "1968 Annual Survey".

[291] "1967 Concentration Ratios", p. 31, 38.

THE STANDARD INDUSTRIAL CLASSIFICATION SYSTEM FOR

THE COMPUTER INDUSTRY (SIC 3573)

| SIC CODE | NUMBER OF DIGITS | DESIGNATION | NAME |
|---|---|---|---|
| 35 | 2 | Major industry group | Machinery, except electrical |
| 357 | 3 | Industry group | Office and computing machines |
| 3571* | 4 | Product group or industry | Computers and related machines |
| 3573 | 4 | Product group or industry | Computers |
| 35710* | 5 | Product class | Parts and attachments made especially for computers |
| 357330 | 6 | Product class | Parts and attachments made especially for computers |
| various (3573111 to 3573331) | 7 | Products | Various products of the manufacture listed in Table 6A of each industry group surveyed. Could be a teletypewriter console or a semiconductor. |

Table XII

The structure of the computer industry, in terms of the number of sellers and buyers is relatively small. Eight to ten firms produce more than 90% of the output (98% according to the data from Dr. Hamid's study in 1966), and a total industry membership of 134, 140, or 178 firms which limit actually is determined by the number of employees. The Department of Commerce did not canvas firms with fewer than ten employees, although it estimated that there were nine firms with one to four employees accounting for $400,000 in value of shipments; and an estimated six firms with five to nine employees, accounting for $1.2 million dollars. The concentration has other determinants depending upon the degree of specialization in the product represented by the firms categorized by any 4-digit group, and these factors will be further examined in a subsection titled, according to Professor Scherer's outline, "conglomerateness".

The number of buyers cannot be accurately determined in the computer industry. One indicator of this element of the market structure is the cumulative net systems installed. Then if one desires to consider any further refinement, for such reasons as allocation of marketing resources, additional reference data might include the annual inventory of computing equipment in the federal government, supervised by the General Services Administration.[292] The current inventory identifies 5277 systems in the federal government, and provides a detailed

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[292] U. S. Bureau of the Budget, "Inventory of Automatic Data Processing Equipment in the Federal Government," U. S. Government Printing Office, July 1970, Charts 1-4.

account of the number by method of procurement, geographical location, and indeed management classification of employment. It also provides a detailed account by manufacturer, and it must be noted that this count does not conform to the output statistics of Table III. This provides a caution for deriving any cabinet-counting technique, unless dollar values are also applied, which are not so provided in that inventory. The distribution by manufacturer is reproduced as Table XIII, and to assist in comparing just how the federal government compares as a large buyer, Table I may be used which includes cumulative systems in use, from Standard and Poor's "Basic Analysis" of a comparable time period.[293] The latter is an inventory or count of the net number of systems shipped and in use by U. S. manufacturers covering a ten year period, with data from <u>EDP Industry Report</u>. From this data it can be noted that, although the U. S. Government was a significant user of the computer industry's output at its inception less than twenty years ago, it operates only about 5% of the systems in use based on 1970 data. The 109,800 systems estimated to be in use and the 5,277 accounted for by the government inventory do not of course represent the dollar value of the investment.

2. <u>Product Differentiation</u>

Having examined the very large number of possible differences in computer hardware, much of which has been made possible by a well-organized and financed technology, one can then multiply those differences many times by the

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[293] "Basic Analysis", p. 013.

CHART 3

# DISTRIBUTION OF COMPUTERS BY MANUFACTURER AND AGENCY AS OF JUNE 30, 1970

| AGENCY \ MANUFACTURER | BUR | CDC | DEQ | HON | IBM | NCR | RCA | SDS | UNI | OTHER | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ATOMIC ENERGY COMM. | 2 | 63 | 371 | 27 | 107 | - | - | 38 | 6 | 140 | 754 |
| AGRICULTURE | 1 | 8 | - | - | 26 | - | - | - | 6 | 1 | 42 |
| COMMERCE | - | 7 | 5 | 3 | 24 | - | 2 | 5 | 10 | 17 | 73 |
| TRANSPORTATION | - | 1 | 5 | 10 | 86 | - | - | 2 | 10 | 4 | 118 |
| GEN. SERV. ADMIN. | - | 2 | - | 6 | 4 | - | - | - | 3 | 12 | 27 |
| HEALTH, EDUC., & WELFARE | - | 7 | 9 | 5 | 55 | - | 14 | - | 1 | 5 | 96 |
| INTERIOR | 2 | 7 | 2 | 2 | 26 | - | - | - | 4 | 3 | 46 |
| NAT'L AERO. SPACE ADMIN. | - | 69 | 52 | 62 | 86 | - | 1 | 140 | 162 | 120 | 692 |
| TREASURY | 1 | - | - | 29 | 33 | - | 1 | - | 1 | 7 | 77 |
| VETERANS ADMIN. | - | 1 | - | 1 | 39 | - | - | - | - | - | 41 |
| OTHER CIVIL | 2 | 9 | - | 18 | 61 | 2 | 10 | 2 | 3 | 5 | 112 |
| AIR FORCE | 179 | 76 | 15 | 35 | 249 | 137 | 58 | 11 | 366 | 84 | 1,210 |
| ARMY | 9 | 46 | 10 | 32 | 267 | 172 | 46 | 9 | 266 | 70 | 927 |
| NAVY | 7 | 93 | 30 | 41 | 255 | 10 | 31 | 20 | 156 | 251 | 894 |
| DEF. SUPPLY AGY. | - | 10 | - | 27 | 47 | - | 21 | - | 19 | 1 | 125 |
| OTHER DEPT. OF DEF. | 1 | 5 | - | 1 | 27 | - | - | 2 | 1 | 6 | 43 |
| TOTAL | 204 | 404 | 499 | 299 | 1,397 | 321 | 184 | 229 | 1,014 | 726 | 5,277 |

Table XIII

18

WORLD-WIDE COMPUTER ACTIVITY AND SYSTEMS

| | Number of Systems Shipped | Cumulative Number in Use | $ Million Value Shipped | Cumulative $ Billion Value in Use |
|---|---|---|---|---|
| E 1974....... | 62,200 | 272,100 | 13,400 | 70.8 |
| E 1973....... | 53,100 | 219,100 | 11,800 | 60.8 |
| E 1972....... | 42,800 | 173,900 | 10,300 | 51.7 |
| E 1971....... | 33,800 | 137,700 | 8,940 | 43.8 |
| E 1970....... | 25,100 | 109,800 | 7,720 | 36.8 |
| 1969....... | 19,650 | 89,400 | 7,170 | 30.8 |
| 1968....... | 14,700 | 69,400 | 7,150 | 24.6 |
| 1967....... | 18,700 | 57,600 | 5,900 | 18.9 |
| 1966....... | 10,200 | 40,600 | 3,660 | 13.5 |
| 1965....... | 7,400 | 31,000 | 2,400 | 10.1 |

E-Estimated

Source: EDP Industry Report, as published in "Industry Surveys: Basic Analysis", Standard & Poors, July 9, 1970, page O 13.

DUPLICATE OF TABLE I ENCLOSED FOR EASE OF THE READER.

addition of constantly improving software, as previously acknowledged by Gregory Chow. The methods by which firms strive to differentiate their products from rivals' have actively followed the early exponential growth of technology noticed by Dr. Schwartz and G. Heilborn. In the simplist forms of competition a participant may alter the price or the product, or both, presumably to maximize profits. In the computer industry, technology has so rapidly improved hardware output performance, as previously noted in the studies of Knight, Solomon, and also Chow and Sharpe, while prices remained somewhat constant, that product differentiation provides a natural shelter for price behavior. Not one of the previously advanced studies asked the question, why did not the hardware price decline as output so rapidly improved. The limited sources of price information indicated that the prices remained constant, i.e., the price tag witnessed by the accounting department of a user. Scherer has noted that, generally, the price decisions are more readily alterable than product decisions, although the computer industry follows the inverse of both. For most industries, as Scherer indicated, the product commitment with both long and short run considerations, leads to a not too severe oversimplification that pricing decisions epitomize the tactical problems of business enterprise, "while product differentiation decisions fall more heavily in the realm of strategy."[294]

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[294] Scherer, p. 324.

Strategy emerges in the short run, however, in the computer industry, with a phenomenal five year new product cycle. It becomes important to review the basic forms of product differentiation to give appropriate recognition to the uses of this differentiation, and later to some of the consequences.

The first and most important form of differentiation is the physical product differences, both actual and implied. Manufacturers will differentiate products so as to display an adaptation or improvement over competing products, yet still within some accepted normal range of capabilities. Some standards have emerged with U. S. Government encouragement in ASCAI for character capacity representation, and the direction of the Department of Defense that COBOL language capability be included in hardware procured under its authority. The market mechanism has been seen to provide a measure of commonality among manufacturers, who desire their hardware to be as general purpose as possible so as to compete for a maximum of different application requirements (demand). Product differentiation must also be accomplished within competing capabilities of peripheral equipment and a large range of software, including systems software, compilers, and translators.

A second form of differentiation is service. Hardware and software services' pricing methods have provided a major test of a very complex pricing system in the computer industry. Hardware and software prices have been intricately combined by most manufacturers, in such a way as to present to the

buyer a wide variety of packaged prices. This method has been attacked by the independent software firms under various charges of unfair competition and monopolization. These matters will be examined in a review of cases in the section on public policy. Generally, separate pricing has become an accomplished fact, and is often referred to as "unbundling". It will be seen that the large manufacturers which have unbundled hardware and software prices, have slightly reduced equipment prices, and introduced services' prices which are significantly higher than previous combined charges. Nonetheless, the full effect on differentiation based on services, since the unbundling of June 1969 are being overshadowed by the new hardware announcements, and prices, of 1970.

Differentiation of products by the application of essential services is especially important in the computer industry. Professor Hamid found that computer manufacturers have had considerable freedom in the market to assign prices different from those of their competitors; and the degree of price variations depended upon the product differences in terms of performance. Performance which is surrounded with essential services provided considerable latitude for differentiation.[295]

A third form of differentiation, location of a plant or factory convenient to a locus of buyers, is not important in the computer industry. One of the leading reasons for

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[295] Hamid, Chapter II, and p. 34.

this is that the effect is normally accomplished in the above category of service. Programming, engineering, and systems services are frequently provided readily available to most customers, and in the case of large users or complex systems, such services are often available at the location of the equipment.

One of the results of the availability of service is a quality product image, which is carefully maintained in the computer industry. This fourth important form of product differentiation will require further discussion in advertising and promotion under market conduct. In a market structured under the dominant leadership of a proven promotion expert, differentiation on the part of the competetive fringe of followers, becomes a task of either establishing overwhelming technical advantages as was seen in the historical development of Control Data Corporation, or a task of displaying to prospective buyers that its product accomplishes as much or more for a lower price. The literature of the computer industry is very much dedicated to endless comparative discussions of these differences.[296] That a useful service is thereby performed in informing the buyers and users is not questioned, but will be examined as part of conduct and performance in the industry.

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[296] For example, periodic articles in Datamation's "Perspective" follow major equipment announcements, which compare and analyze specific configurations. "RCA's New Line", and IBM's 370/145 Uncovered", of October 1970 and November 1970 "Perspective" sections are recent examples which provide announcement data.

3. <u>Barriers to Entry</u>

The appearance and disappearance of firms in the computer market was described by Dr. Hamid as characterized by limited freedom.[297] It can be observed as considerably more limited with respect to the manufacturing of digital computer equipment. Some of the leading inhibitors of entry are:

a. A very high capital requirement to support the costly, long term production cycle.

b. Technical complexity of hardware and logic designs requires personnel capabilities, at the limited scientist and engineering levels.

c. The innovative capabilities as a limited resource are further constrained by the patenting consideration, as noted earlier.

d. The noticeable absence of profits for several years permits only large well-financed manufacturers to attempt entry. Major firms such as NCR, RCA, Burroughs, Sperry Rand, and General Electric have experienced long periods of unprofitable computer production. The partial withdrawal of GE from computer manufacturing, and the re-defining of its objectives toward the time sharing segment of the computer market, is the observed reaction of the fourth largest U. S. corporation according to the <u>Fortune</u> top five-hundred survey for 1970.[298]

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[297] Hamid, p. 35.

[298] <u>Ibid</u>. See also "Fortune 500, 1970," p. 184-185.

A substantial and intriguing body of economic knowledge in the field of price theory and the relationship to entry, is beyond the scope of this review, however Dr. Scherer's text provides an excellent entry into the literature of current analyses, in his chapter on "Pricing to Deter Entry". Application of existing theories to the computer industry is particularly difficult in the examination of entry and exit of member firms, because of the long reaction time as noted of major firms above, the absence of price and cost statistics to determine possible entry conditions on the competetive fringe, and the unmeasurable effect of technology with its related innovation announcement cycles. It can be generally observed that to date in the young computer industry, prices have apparently not risen sufficiently high to encourage a large new entry of competitors. The new developments in the small, or mini, computer market, and IBM's belated entry into that field could be the first hint of open entry for a producer with existing capability and marketing expertise. The growth of the small computer market perhaps could be the target of such new entrants as Xerox and Texas Instruments. The sizable technology and expertise barriers are attainable through different avenues by these two firms. Survival through vertical integration is another possible explanation which will require more time to evaluate.

Dr. Hamid has noted that exit from the computer industry is also quite limited judging from the present behavior of the firms. He outlined some of the closely

related industries in which the major computer manufacturers participate, and theorized that such firms use these "other" product lines to earn a sufficient profit to permit the computer division to operate partially as a research facility.[299] He also considered the prestige or reputation of each of the eight leading firms to be a significant deterrent to exit by the large multiproduct firms. Finally, he reported that the existing firms which were experiencing heavy losses had recognized that potential upon initial entry and nonetheless persisted in pursuit of long run project expectations.

Limited entry into computer manufacturing is not concluded to be the single source for price level maintenance by the industry's limited number of members. The fact that entry is inherently limited is sufficient knowledge for a dominant firm to exercise its full market power, as will be seen in pricing behavior.

4. Cost Structures

Although prices and costs have been noted to be of questionable value in the computer industry, the inability to predict costs is not an unusual phenomenon, and certainly no reason to adopt the Cyert-March theory to explain cost projections.

Uncertainty in predicting costs is a most controversial issue among financial experts in business, and is abundantly discussed in the literature. The Cyert-March

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[299] Hamid, p. 35.

departure from the traditional theory of the firm suggests that uncertainty is avoided by the use of decision criteria which feature short-run reaction to short-run feedbacks, thus circumventing the need for quantitative anticipation of future events.[300]

The decision making within the firm based on short-run reaction to events and short-run feedback of new information is not precisely descriptive of the computer manufacturer with respect to decisions which involve new technologies or commitments of large amounts of capital to new families of computers. Manufacturers have been noted to endure long periods of outflows of funds without any feedback on prospective returns, or a point in time when a break-even point between receipts and expenditures can be identified. The application of the Cyert-March theory of the firm to these long periods of technological development and marketing might be explained as a series of intermediate steps which could perhaps be described as short-run reaction to short-run feedbacks. However, this cannot adequately present a complete description of the long range objectives or parameters within which such short-run decisions are made. The decision of General Electric in the early part of 1970 to redefine its hardware manufacturing objectives and to retain only its time-sharing capacity, was made after several years in the computer manufacturing field. Such decisions do not appear to be the result of short-run reactions to short-run

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[300] Cyert, R. M. and March, J. G., Behavioral Theory of the Firm, Prentice-Hall, Inc., 1963, p. 119.

feedback, but the failure to meet long-run objectives, and the setting of new long-run objectives in the developing time-sharing market.

It became virtually impossible to make any useful comparison between the Department of Commerce statistics and the income and operating statements of various firms. IBM, for example, in addition to making typewriters and dictating equipment, reflects gross revenues of over $2,000 million from the IBM World Trade Corporation which is a wholly owned but independently operated subsidiary. Thus sales or gross revenues have an indeterminate amount of input resulting from other industries or sources. Nonetheless Table XIV reflects this reported information, and it is interesting to note the differences in capital expenditures and inventory information for this 1967 data.

The cost structure of the market mechanism has become of interest to conduct and performance because of what Richard Caves refers to as absolute cost barriers.[301] The effect is to place the curve for average unit cost of production for a new firm above that of an established firm, so that there is a cost disadvantage at any level of output. For both firms these costs are high at the low-output volume level and gradually decline as output increases. However, owing to patents and cost of capital to prospective new entrants, the beginning average cost curve is so prohibitive

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[301]Caves, p. 26.

1967 BALANCE SHEET AND CENSUS DATA

| The Computer Industry (SIC 3573) 1967 Census<br><br>Department of Commerce | 1967 Data as Reported in Standard & Poor's Corp. for IBM |
|---|---|

| | | |
|---|---|---|
| Value (shipments) | $3,770.9 | |
| Gross Income | | $5,345.7 |
| Capital Expenditures | 117.1 | 1,469.9 |
| Inventories | 985.6 | 214.1 |
| Payroll | 803.5 | |
| Cost of Materials | 1,875.6 | 2,570* |
| Operating Income | | 2,171.3 |
| Net Income | | 651.5 |
| Depreciation, Amortization of Patents and Good Will | | 871.6 |
| Current Assets | | 2,078.6 |
| Current Liabilities | | 1,162.2 |
| New Working Capital | | 916.4 |
| Long Term Debt | | 521.5 |

Number of Shares (113,718,068)
Book Value 34.4 (1967)
Additional Statistics for 1967 Census:

| | |
|---|---|
| Payroll per Employee | $8,124 |
| Average Production Wage Hour | 3.02 |
| Cost/Material per $ of Shipment | .50 |
| Cost/material and payroll per $ Shipment | .71 |
| Value added per man hour of production worker | |

*Estimated by authors using Standard and Poors 48.3% COM ratio of 1967.

Table XIV

Sources:

U. S. Department of Commerce, 1967 Census of Manufacturers, Industry Series, October 1970, page 35F-11; and Standard and Poor's Corp., N. Y. S. E. Reports, Vol. 37, No. 183, September 22, 1970.

as to be an absolute barrier to entry. Further, the research and development costs to develop a different (differentiated), patentable product, and the cost to maintain such unique technology, plus the cost of services necessary to competitively present a somewhat homogencus product, operate as major cost deterrents in the market mechanism. However, if the dominant firm errs by setting prices too high, entry could become possible at an earlier point along such curves. That market share has maintained a level of consistency over the past several years would indicate that such price policy is well under control by the dominant firm in the computer industry.

Another unique factor of computer industry marketing practice has had a significant effect on the maintenance of dominance, and that is the need for capital. Not just the capital-intesive production previously described, but the additional capital needed to finance the method of marketing the computer, sometimes referred to as renting by the manufacturers. Standard and Poor's estimates that sales have continued to decline as opposed to leases of computers in 1970, and such deferred income to the rest of the industry which such rentals represent, have required heavy capitalization. In a high interest rate environment, the marketing of computers at prices which have tended to be stable has, as Standard and Poor's acknowledges, a "decidedly negative impact".[302]

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[302]"Current Analysis", p. 02.

5. Vertical Integration

Vertical integration is the combination in one enterprise of those establishments related as customers and suppliers. The 1967 Census data relating to concentration ratios has indicated that the number of members in the computer industry who tend to specialize in the products regarded as primary to the industry is estimated to be above 90%.

Such specialization is not directly the result of vertical integration, but serves to help explain one of the basic conditions, business attitudes, which has developed from the history of the industry. The desire to provide a high quality, complete service was noted to be a stated goal of IBM. The incidental products to this goal found IBM operating in the supplies, hardware services, and software markets. In each of these markets IBM and its followers strive to maximize their market shares. Supplies include a nebulous array of tapes, disk packs, ribbons, cards, specialized tagging, labeling and filing devices, and a recent entrant, microfilm.[303]

IBM has long dominated the punched card market of the supply category. In 1969, Standard and Poors' "Basic Analysis" estimated that peripheral equipment represented more than fifty per cent of the installed equipment value, and that the leading hardware manufacturers accounted for

[303] "Basic Analysis", p. 013.

94% of that production.[304] The reaction of the independent firms has been to apply about ten per cent of sales to research and development, in order to continue to produce proprietary products which now include software. The financial drain has been so heavy on these firms that third party leasing arrangements have become the only avenue of survival in peripheral hardware manufacturing, which has become a significant and similar subset of the computer industry.

Software is said to have closely approximated the value of hardware in sales value in 1968,[305] but a qualification cited by Standard and Poor's was that 90% of that value was actually "developed by computer users, as opposed to computer manufacturers and independent software companies."[306] The table which supported that 1969 data differed considerably from the one used in the July 1970 "Basic Analysis".[307] Both tables referred to EDP Industry Reports. The most recent is presented in Table XV to represent the importance in sales value of the hardware (main-frame central processor units and peripheral equipment), software, supplies and services.

Another form of vertical integration flows from raw materials to finished goods. It was earlier noted in 1964, that IBM vertically integrated backwards when it entered into semiconductor production.

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[304] "Basic Analysis, 1969, p. 08, 09.

[305] Ibid.

[306] Ibid.

[307] "Basic Analysis," p. 013.

WORLD-WIDE REVENUES OF AMERICAN-BASED

COMPANIES FROM KEY FACTORS OF THE ELECTRONICS
DATA PROCESSING INDUSTRY

| | *Computers | Independent Peripheral Equipment | Data Processing Supplies | Computing & Data Services | Control & Packaged Software | Total |
|---|---|---|---|---|---|---|
| E1974 | 16,370 | 1,340 | 1,610 | 2,440 | 2,560 | 24,320 |
| E1973 | 13,980 | 1,100 | 1,500 | 2,130 | 1,970 | 20,680 |
| E1972 | 11,930 | 890 | 1,390 | 1,810 | 1,470 | 17,490 |
| E1971 | 10,120 | 710 | 1,290 | 1,500 | 1,050 | 14,670 |
| E1970 | 8,580 | 560 | 1,165 | 1,200 | 700 | 12,225 |
| 1969 | 7,210 | 435 | 1,075 | 940 | 450 | 10,110 |
| 1968 | 6,425 | 360 | 960 | 715 | 270 | 8,730 |
| 1967 | 4,840 | 270 | 850 | 530 | 175 | 6,665 |
| 1966 | 3,585 | 180 | 740 | 485 | 100 | 5,030 |
| 1965 | 2,790 | 150 | 660 | 355 | 50 | 4,005 |

*From rentals and sales

E Estimated

Source: EDP Industry Report, as published in Standard & Poors Industry Surveys: Basic Analysis, Section 2, July 9,1970, p. C 13

Table XV

6. Conglomerateness

Conglomerateness is a general form of integration which proceeds across organizational lines to achieve certain economies of market or product extension. A trend toward conglomerate merger despite antitrust activity, was reported after extensive studies by the Federal Trade Commission and Antitrust Committees which covered a seventeen year period. The most recent trend towards conglomerate mergers does not reflect product or market consummation; rather the past five years have witnessed mergers which resulted in dissimilar products or services, of the category described as diversification.[308] Nevertheless, there were 216 product extension conglomerate mergers and one market extension type in the 1967-1968 period; and a total number of mergers (vertical, horizontal, and conglomerate) of 361.

Many computer manufacturing firms operate subsidiaries to extend their image to services, software, maintenance or supplies. Some of the leading firms moved into computer equipment from primary industries such as electrical equipment, television, and accounting machines, but recent 1970 developments indicate some movement is proceeding beyond the manufacturing level. Control Data Corporation recently acquired Commercial Credit Corporation which in turn is a holding company with subsidiaries engaged in three other businesses of lease-financing, insurance, and manufacturing.

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[308] Scherer, p. 109-115.

The acquisition was reported to be prompted by the need to build liquidity reserves.[309]

RCA is another example of a large well established hardware manufacturer, and operates in such diversified fields as those represented by the Hertz Corporation, Random House, NBC, and a global communications subsidiary.

Burroughs has remained in the four basic divisions of the industry but operates an active and profitable international group.

IBM was previously reported to operate an international World Trade Corporation; it also operates the Service Bureau Corporation which provides a broad range of services including time sharing. IBM also controls Science Research Associates which develops and publishes educational material.

General Electric and Honeywell likewise operate in a broad range of related and service-oriented firms and subsidiaries. When they jointly announced plans to transfer most of their respective computer operations to a new company, on May 20, 1970, the first example of a major move out of the computer industry was provided; the residue is a conglomerate merger.

The public policy section will present some of the current antitrust actions which have as a secondary role, the divorce and divestiture of the major subsidiary groups of the dominant firm.

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[309]Standard and Poor's Corp., "Standard NYSE Reports," Vol. 37, No. 173, September 8, 1970, Section 11.

The market structure in the computer industry has been described by Schwartz and Heilborn as the structure determined by IBM. They readily conclude that the dominant firm structure includes eight to ten small followers who divide about 25% of the computer market. IBM has determined that it prefers to lease its equipment, with prices based on usage, because it is a service, and IBM has many related services to sell. This indeed has been seen to be part of the existing structure in barriers due to capital requirements, cost structures which extend over considerable time, and a form of specialized, technical service which attracts no take-over oriented conglomerates, doubtless because of the capitalization ratios.

C. CONDUCT

Having described the history, basic conditions and general structure of the computer industry, it is now appropriate to examine the causal flow of these determinants into the pricing and product. The importance of the structure is in the way it induces member firms to behave. Such behavior includes setting and changing prices, output, products, services, research advertising and legal tactics which provide for a boundary of conduct. Ordinarily in oligopolies, the few firms so recognize their interdependence as to react to one another; this has been noted to take place in technology announcements, counter-announcements and replies. This action and reaction brings clever game theory possibilities to the computer market, except that the strategy variables are weighted by market share and the dominance in that area must be adapted to a more practical form of price leadership.

1. Pricing Behavior

Having reviewed several possible pricing schemes, the dominant firm model was selected as representing a special form of price leadership in the computer industry. It is considered special because it does not result in a common dollar price mechanism, but a uniform pricing scheme that has been described in the literature as the "umbrella" effect. It has features other than subtle price leadership, which still permit oligopolies mutual interdependence and account for rigidity of prices from list price schedules. The action and reaction of a few sellers in the market based on market share was the first consideration of Kaysen and Turner in developing a set of criteria concerning the conduct in a concentrated oligopoly.

The dominant firm model of Cohen, Cyert and Ferguson,[310] uses a basic assumption that the dominant firm sets the price and allows the minor firms to sell all they can at that price; the dominant firms sell the rest. This model adequately describes the computer industry.

In Figure 5, D D' is the market demand curve, SM is the supply curve (and marginal cost curve) of the minor firm, and MC is the marginal cost curve of the dominant firm. At a price of OC the competitive fringe of firms supply CD, and with total demand CF, the dominant firm supplies DFat the OC price; E is a point on the dominant firms' demand

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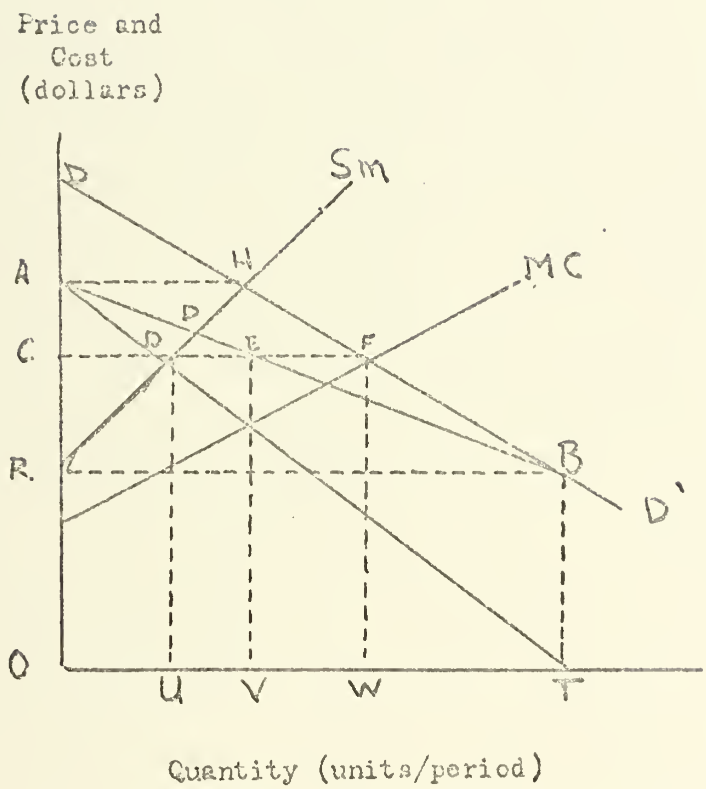
[310] Cohen and Cyert, p. 241-243; Ferguson, C. E., Microeconomic Theory. R. D. Irwin, 1961, p. 328-329.

DOMINANT THEORY OF THE FIRM MODEL




Source: Cohen, Kalman J. and Cyert, Richard M., _Theory of the Firm: Resource Allocation in a Market Economy_, Prentice-Hall, 1965, pp241-242.

Figure 5

curve (CE = DF). The marginal revenue curve, AT, for the dominant firm intersects the marginal cost curve at output OV and thus the price would be set at OC in Figure 5.

Figure 5 is not proportionately representative of the computer industry, and indeed, little is known about the marginal cost and marginal revenues of the dominant firm. To maximize long-run profits, the dominant firm could establish a price below OC, at the intersection of AT and MC, and by way of short-run price wars could drive any number of smaller firms from the market. The dominant firm needs to know the industry demand curve, its own marginal costs and marginal revenues, and given that the smaller firms will equate marginal cost and price, it can identify the supply curve (SM) of these dominated firms. To arrive at the demand for the dominant firm, the procedure is to set a particular price, compute the amount of computation or computers which the minor firms would sell at that price, and subtract that amount from the total demand at such assumed price. The total demand is seen to be OW where OW = OU + OV. The amount supplied by the smaller firms is CD. The model thus explains how a dominant firm can determine the price which will maximize its profits while allowing the smaller firms to sell all they wish at that price, by computing its own demand curve. It will not lower prices to eliminate its rivals because of possible legal difficulties under antitrust laws. It could however, estimate a market share, and attendant output quantity, beyond which such legal action would likely occur, and establish a pricing policy which operates within

such constraint. It would be more difficult perhaps to determine such a threshhold of antitrust reaction by other firms or on behalf of the Justice Department. This relationship between the dominant firm model, market shares, and the hiring of former Justice Department attorneys will be examined in the section on public policy.

Studies have indicated that U. S. Steel with its dominant 75% of the market in 1903, operated as the dominant firm model indicated. But by 1920 it controlled only 50%; and in 1960 it averaged about 25%, but remained the price leader.[311]

Price leadership is a divisible factor of the model; the dominant firm presents a list price for a representative range of hardware configurations. The competitive fringe of followers is noted to find its price somewhat below the leader but the pricing prior to unbundling makes it very questionable as to the resultant value in services and product which could be obtained. Yet Schwartz and Heilborn carefully note that IBM sold hardware only because of the 1956 antitrust consent decree and used its dominance to establish an industry pricing behavior that is complex, yet has favored rental over purchase. The ratio of rental to purchase prices, negligible residual values at the end of the four or five year depreciation cycle, and a higher cost of maintenance on purchased equipment, are cited as encouraging a preponderance of leases. Since that report in 1967

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[311]Cohen and Cyert, p. 240-243.

(and Dr. Schwartz' former status as corporate econometrician with IBM lends stature to his arguments), the growth of the used computer market could alter the residual value concept sufficiently to favor purchase of more hardware than Dr. Schwartz envisioned. Yet he provided a behavioral interpretation to the dominant firm model in recognizing that the apparent price to the customer is regarded as a flexible price he can terminate. He further states that only when the competition has taken the technological lead has IBM exercised its dominance, and outdated its equipment. This product strategy is seen to depend heavily on its ability to innovate according to a pattern that is dependent on price dominance indirectly and overall market power directly.[312]

2. <u>Product Strategy</u>

The ability of computer manufacturers to introduce new equipment and apply technology to business automation problems has been widely expressed in the literature. But pricing policies have been seen to be the silent controllers, while product strategy is the result of the structure of the technological industry. And that structure has been seen to be significantly influenced by the overwhelming market share of its leader. Yet market share was found to also be expressed in terms of the number or value of installed equipment, and not just sales alone. Table III demonstrated that the differences in shares between shipment values and installed values differ only slightly.

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[312] Schwartz and Heilborn, p. 22-24.

One product strategy noted by Schwartz and Heilborn was the slowing of the rate of innovation by IBM's leasing policy. Yet it was also acknowledged that IBM did not control the initiation of new products and it had to react to the occasional introduction of an innovative hardware design. Its reaction was not in the price dominance, but a coefficient of lesser magnitude: reactive product strategy. The introduction of Control Data Corporation's large computer and IBM's reaction has become an example of a communication breakdown in the interdependency of oligopolies. Their suit will be examined shortly.[313]

The overall product strategy requires a considerable organization in the development and research to produce new items, but an equally great marketing and services function to maintain the differentiated strategy. Although Caves has observed of oligopolies, that product strategy is more likely than price strategies to satisfy the requirements for independent action, that an initial move will not be met by rivals, the computer industry again has been seen to not follow some of these basic characteristics of oligopolies.[314]

The strategic importance of generations and model changes scale economies in the computer industry depends upon a special interaction of technology, constant growth of users' applications, and the industry's institutions.

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313 ___ "Tackling IBM," <u>Time</u>, December 20, 1968, p. 77, hereafter cited as "Tackling".

314 Caves, p. 49.

Scherer and Lanzillotti and others have noted these special considerations in the auto industry with annual style changes.

This product strategy was previously discussed in the section on market structure, as having evolved historically with the capital intensive production, and maintained by a high capital requirement to finance the rental of a very costly product. Thus this strategy has been found to weigh very heavily on the need for large research and development expenditures by the hardware manufacturers. IBM was reported to have expended between $10 and $15 million in attempt to develop a computer technology based on cryogenics (low resistance behavior of certain metals at absolute zero); the effort was dropped in 1961 as System 360 planning and technology development moved into central concern. Thus, not all expenditures result in a production line technology. A strategy of constant technological development has required the very best in engineering and scientific talent. For example, in 1965 IBM hired Eugene Fubini directly as a group vice-president (from an engineering deputy level in research in the Defense Department). A large talent search is part of all manufacturer's product strategy and considerable rewards await useful contribution. It is thus seen that the research and development factor of product strategy includes a costly personnel input.[315]

The emphasis of product strategy apparently cannot be directly determined from the literature because of the absence of specific cost data. It is nonetheless estimated that independent peripheral manufacturers have expended 10% of

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[315] Wise, "Rocky," p. 139.

their sales dollar toward product research. In 1961 Control Data spent $2.6 million (6.3% of sales) on research and development while IBM spent an estimated $100 million.

Product strategy in market conduct has been seen to favor leasing, with complex price schedules that frequently extend over dozens of pages in itemizing the many contributions of specific hardware, memory sizes, peripheral controllers, and related components. The separate pricing for some services following unbundling has presented a cost disadvantage to some of the leasing firms, especially noted with the introduction of the IBM System 370 computers and the related new price schedule.[316] Consequently, the nature of the product with its necessary related services requires that hardware manufacturers adopt a product strategy, and services strategy which together, present the most attractive combination in the market.

The need to maintain product compatibility, that is, among main central processors and a wide variety of peripheral equipment, was discussed as an essential consideration to differentiation. It is particularly important to the smaller manufacturers which do not produce complete lines of hardware, particularly central processors, and therefore must address their products to existing markets in a dependent manner. L. R. Caveney, who is president of the Computer Peripheral Manufacturers' Association, representing some of the smaller, independent peripheral manufacturers, recently stated that

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[316] McLaughlin, p. 30-31.

this component compatibility would be facilitated by effective standards for mechanical and electrical interfaces. EDP Weekly, which reported Caveney's comments, also noted that it is frequently difficult to obtain specific technical information concerning IBM systems, unless IBM "has chosen to release it".[317]

Another example of product strategy reached the busy Southern District of New York court on April 21, 1970 when Xerox entered a patent infringement suit against IBM who had decided to market a competing copier, following Xerox' entry into computer manufacturing by way of merger.[318] The complexities of the patents extend back to 1951 and 1955 when IBM received licences under Xerox (Haloid) patents which revealed technical knowledge to a special photocopy process. The product strategy and legal tactics are not only linked in these details, but some additional uses of that photocopying process in output devices is currently under study, with a strong potential market for copying output devices. The more obvious strategy is more in the tactics of each of these giants stepping into one another's market boundaries. The conduct is clear: IBM was willing to wait for the patents to run, having paid nothing in royalties which were stated to be 27% of any resulting net selling price.

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317 EDP Weekly, Vol. II, No. 25, October 5, 1970, p. 9.

318 EDP Industry Report, Vol. 5, No. 12, April 27, 1970, p. 1-5.

Product strategy has been seen to include a careful application of technology to produce new hardware designs which demonstrate improved performance and which are surrounded with all the essential services which the market requires. However, the strategy in relation to the dominant firm has been seen to follow the leadership in new product announcements. After the IBM 370 announcements (prior to 370/45), RCA aimed its new line at the IBM 360s and 370s and declared them to be equivalent products at a more advantageous pricing arrangement.[319]

Yet this mutual interdependence among firms is not, judging by the competitive conduct, expecially cooperative nor is there any indicated collusion. Product strategy determines price behavior and depends on the full range of supply elements outlined in the supply section of basic conditions. It is seen to be highly interactive among firms, with clear and direct leadership of the type engendered by the umbrella effect. Once IBM has announced a new line, a technologically oriented scramble occurs to present "equally-capable, but different (better)" products and related services.

3. Research and Innovation

The rapid growth of the computer industry has required skillful application of the resources; the technology at its disposal at any time was seen to also be advancing at a rapid rate. Such continual innovation has not been uncriticized,

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[319] Pantages, "RCA's New Line," p. 30-31.

and the literature has met each innovation announcement with analyses that suggest market-share maintenance, or forced obsolescence to amortize existing development costs.

Research and innovation, however, are part of a continuous process the accumulation of which cannot be dispensed as rapidly as new drug products nor marketed without due concern for the existing hardware in the hands of users and the resultant need for compatibility with the systems and software necessary for a successful application. Such conduct is especially important to a manufacturing group which prefers to rent to its customers and thus has to prepare realistically against termination for cause.

Research and innovation are thus important to the image of the firm and it is a two-way cause. The results of that effort at any discrete point along the development process must be (1) a new quality product needed by the user, and (2) one that works well, competitively. Not all firms have used research to innovate; followers are prone to apply research in product development which essentially emulated the dominant leader. A recent discussion of the constant effort of peripheral manufacturers to maintain "plug-to-plug compatibility" with main frame hardware producers while offering an advantageous product, places this form of technology in the performance race in the factors of: access time, reliability, maintainability, and price.[320]

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[320] Frost, Cecil R., "IBM Plug-to-Plug Peripheral Devices," Datamation, October 15, 1970, p. 24-34.

IBM was seen to expend $10 to $15 million on a technology which did not result in a product. Dr. Hamid found by survey that manufacturers allocate about nine per cent of their total cost to research and development. He also reported the results of a Stanford Research Institute study of 80 firms which were considered high investors in research and development and it determined that 7.2% of sales was so allocated.[321]

Many do not have the resources to attempt to advance the state of the art in peripheral design. So there is an umbrella effect in research that invariably relates to capital intensiveness, that the large firms lead in basic research and in developmental research, while smaller manufacturers can compete only on the development and research level that produces like products.

It is readily acknowledged that the above observation of research umbrella effect in the computer industry does not follow some of the results of previous studies examined in the section of basic conditions. Scherer's separate study of "Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions", concluded that the evidence is to the contrary. Corporate bigness was found to not favor inventive output when testing the concentration of sales, R and D employment, and the number of patents in an industry sample of 352 firms.[322]

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[321]Hamid, p. 119-120.

[322]Scherer, "Firm Size," p. 1103-1114.

The umbrella effect of the dominant firm in the computer industry over sales and innovation is perhaps a result of more factors than Scherer had tested, although his study used 1955 data and 1959 patent information which would describe a very early period of computer industry growth. It is not known whether sufficient data were available to have included the computer industry in his study. Nonetheless, one additional factor in the computer industry is the high degree of specialization reported earlier from the Concentration Ratio report of the Department of Commerce. This specialization also requires the firms in the industry to apply heavy amounts of capital to compete in the development and production of their primary products. Reports for the Fourth Generation's innovations do not support a conclusion that the leading firms were not proportionately represented in products which required significant applications of research and development capital. Fourth generation hardware reports would also indicate that the industry leaders are well represented in key innovations. Finally, one patent for a transistor or similar key component, would have to be weighted more heavily than several hundred for vacuum tubes or grid designs. The early stages of growth of the industry and its technology could be responsible for this apparent continuance of the umbrella of research and innovation. Smaller firms will be prone to build compatible hardware and peripheral equipment which can assure them of some share of the market.

The slowing trend for this research and innovation, anticipated at some point along a very long industry growth curve by Schwartz and Heilborn, may actually be taking place according to one definition. The trend toward the fourth generation merging of logics, systems and devices into overlapping technologies, was observed in a technical report by Dr. C. J. Walter and A. B. Walter, published recently.[323] This merging effect does not necessarily reduce or simplify innovation in hardware design, but its effect has helped to define computer generations, as presented in Figure 6.

Market conduct of the fourth generation innovation announcements appears to have continued the tactics and strategies presented in product and pricing observation. IBM announced two models of the new 370 line on June 30, 1970 and on September 15, RCA anncunced its response to the new line with various cost comparisons provided by the professional journalists. One week later NCR also announced that a new family of hardware was to be offered. On October 7, 1970 Burroughs unveiled its new family, and offered to replace about 200 B5500 and 6500 systems which were thereby outdated, without installation fees. IBM then began releasing information on its 370/145 which demonstrated the first semiconductor memory breakthrough, and the fourth generation announcements of innovation have now moved into

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[323] Gruenberger, Fred, ed., Fourth Generation Computers: Users Requirements and Transition, Prentice Hall, 1970, p. 12-18.

MERGING OF HARDWARE DISCIPLINES

COMPUTER HARDWARE EVOLUTION

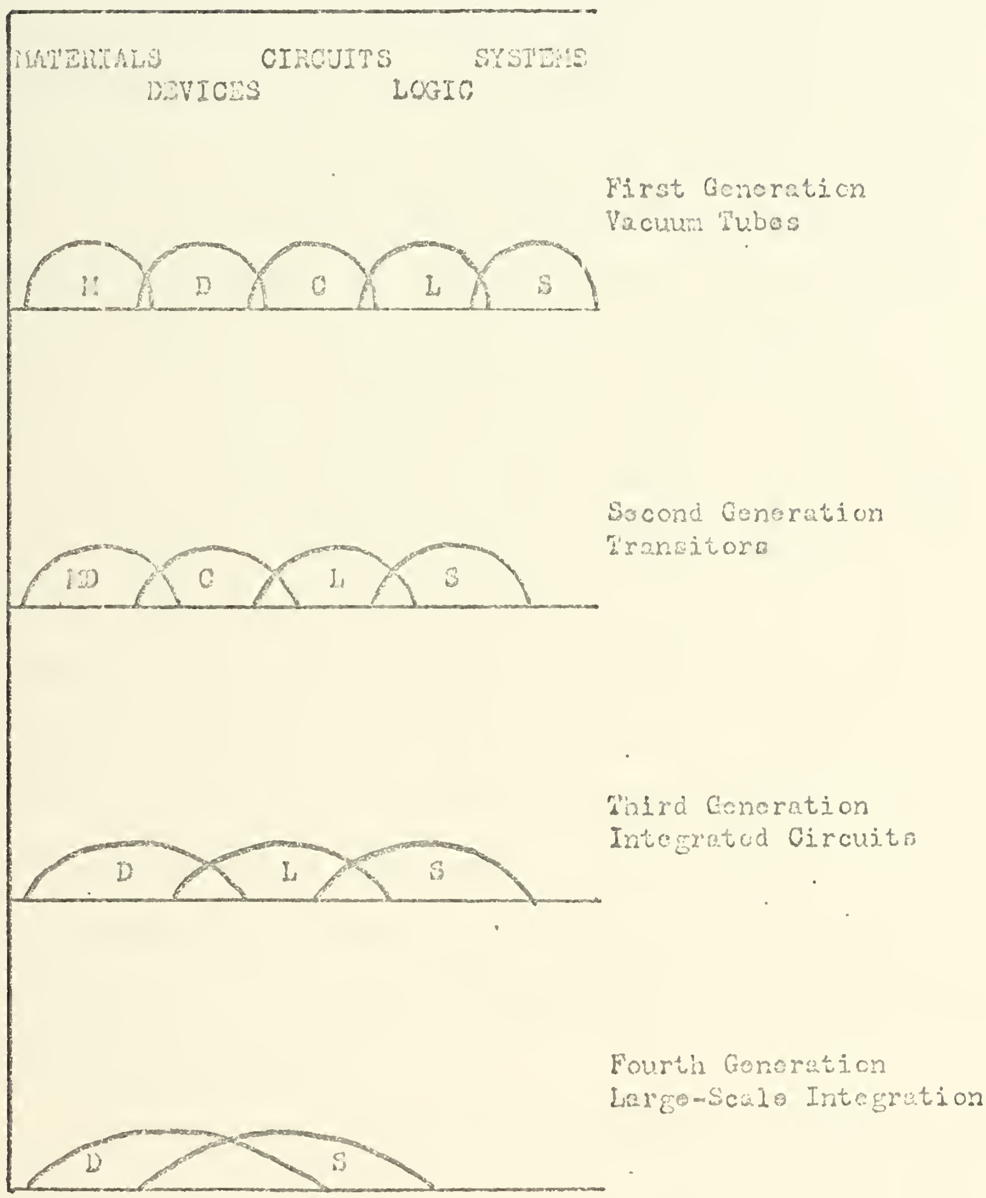


Figure 6

the professional, hard-sell marketing of the industry.[324] That tradition is more marked by the effective marketing organization than by any particular tactics.

4. Advertising

Considerable insight into the nature of computer industry advertising techniques and objectives have now been found in the policies and strategies of research, technology, announcements of new lines, product differentiation and pricing complexities. The advertising of computers is perhaps no different than many industrial products, however it also parallels the professional customer, professional sales-engineer relationship of drug manufacture and physicians. The approach, or strategy, requires direct, detailed account of the effectiveness of products offered to the responsible user. Although the computer manufacturer cannot deliver the free samples as has been customary of the pharmaceutical industry, it nonetheless caters to its existing customers (and probably knows more about the needs and growth of such customer than any other professional advertising and marketing organization); announcement of hardware is occasionally accomplished at demonstration meetings.

IBM's announcement of the System 360 family pushed the concept of tailoring a system to fit a broad range of

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[324] Schmedel, Scott R., "Burroughs Third Maker in '70 to Unveil New Computer 'Family'; Sees Sales Surge", The Wall Street Journal, October 7, 1970, p. 30 hereafter cited as "Burroughs New Family"; and "News Scene: Burroughs' New Series: December (70) Delivery", Datamation, November 15, 1970, p. 123-124; Pantages, "RCA's New Line", p. 30; EDP Weekly, October 5, 1970, p. 2, 7.

needs. It was simultaneously announced at IBM's offices in 165 U. S. cities and 80 foreign countries.

Other forms of professional journal advertising are essentially designed to establish a communications link through an elaborate "reader interest card" system with which several periodicals participate. The levels of response and reply are designed to identify the current interest so that a local representative can be designated.

The order-delivery system found to be inherent in the market structure, also affects the conduct of advertising to emphasize the output of hardware and related characteristics as they apply to a potential customer's requirements. Delivery time and price remain vague or in the background. Once the user becomes a customer it is observed that a very close relationship is maintained and the goals of advertising shift to the customer services responsibility to maintain the customer's satisfaction until added components or upgrading becomes a possibility. At such future time a new form of advertising can be applied in the form of a tailored approach based upon past experience and projected requirements. The incumbent contractor or manufacturer is at that point in a strong position to dominante, depending upon the degree of service involvement of the past. New advertising at this stage is carried on by specialists of the marketing organization variably categorized among the systems analysts and customer engineers.

5. <u>Legal Tactics</u>

Legal actions which have involved the large computer manufacturers have been somewhat limited in scope and in number. The dominant firm has generally been on the defensive against various charges of monopoly, monopolizing and in unfair pricing policies. These matters will be discussed more fully in a concluding section on public policy.

One recent suit involving IBM and the Greyhound Computer Corporation indicated the market conduct implications. Concerning IBM's unbundling policy, Greyhound contends it was:

"... designed to permit IBM to extract higher profits; preclude entry into the computer software industry by use of low-cost pricing for such unbundled services; and destroy the leasing industry, which will not be able to recover the original price (of leased equipment) at the lower (IBM) lease rates."[325]

The suit further contended that it was not possible to compete with IBM because of these adjustments of prices, services and depreciation policies.

Market conduct in the computer industry has been seen to reflect the oligopolistic structure featuring the dominant firm model. The degree of dominance is such that pricing behavior is constructed as part of a full range of services

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[325] EDP Weekly, Vol. II, No. 25, October 5, 1970, p. 5.

surrounding a complex array or family of computers and systems. The product strategy permits the technology to be employed to maintain the high capital employed in its production and marketing through timed generation cycles representing depreciation estimates of capital value. The full life value has been challenged by recent developments in the used computer market, which was, no doubt, of no great surprise to the dominant firm which met this challenge with unbundled prices for software and services which will permit it to share in this new market extension. The timing of these events suggest alertness and ability to react quickly in product and market strategy on the part of the dominant firm. The result is seen to support a progressive image in advertising and marketing techniques. The absence of coercive conduct is in part, displayed by a defensive legal tactics policy, descriptive of the dominant firm structure which does not require such tactics in the short run. Short run product strategy is calculated to produce essential revenues to maintain market share dominance. As Caves and Bain have found, coercive conduct is sometimes found to be necessary to maintain high barriers to entry, which results from high concentration.[326] Such conduct was not found to be part of the market structure.

The reason for concern about market conduct is not just to determine the nature and effect of the structure

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[326] Caves, p. 52-54.

nor to observe whether supply begets demand, or the reverse. The concern is, to the economist, whether scarce resources are allocated without restrictions by an industry's behavior or actions. This concern, is more obviously vital perhaps in consumer goods' industries, the products of which more directly require a consumer to release cash. The process is more indirect in analyses of durable goods which are essentially industrial products. Rigid computer prices to a using manufacturer of a consumer product, are nonetheless, passed on to the consumer who buys the highest priced products; and in part, to the multitude of taxpayers who share the partial tax burdens reflected in investment tax credits and business expenses of any number of intermediary establishments. Therefore, a study of even so limited a product must attempt to equate structure and conduct to performance.

D. PERFORMANCE

Review of market performance in an industry seeks to evaluate how well, or how efficiently, the scarce factors of production have been employed to yield the optimum real income. In that process, full employment is a measure of minimizing idle capacity and progress is a qualitative measure of the improvement of factors, output quality levels, and techniques, and finally, as Richard Caves has defined this purpose:

"Our economy should be <u>equitable</u>, distributing its real output among its members to provide for their essential needs and reasonable expectations as well as rewarding their productive efforts."

The task of performance is to evaluate the economic difference between actual performance and some optimum possible contribution of an industry's market behavior. Such an appraisal is the goal of public policy.

1. Production and Allocative Efficiency

Efficiency in the context of economic performance is normally evaluated according to profit levels in comparison with other industries, expenditures such as advertising and sales promotion, and the resultant effect in extending market power without appropriate production improvement, or general progress.

An analysis of profits is not only made difficult from the absence of statistics in the industry which would hopefully make it possible to determine true profit levels, but the practice of leasing directly from a manufacturer to a user and the deferred income effect, over no specific, identifiable time period with a host of related services and profits therefrom, combine to make such exact figures of questionable value to the purpose of performance evaluation. Some indication will be found in the financial data including net income, of the same leading ten firms which were used to develop market share positions in Table III. This financial information is presented in Table XVI for 1969 data. No attempt has been made to evaluate the computer portion of these major corporations, however, it was noted earlier that several were not yet making profits in their computer divisions. General Electric apparently never has made any profit. Roy Macdonald, president of

MAJOR COMPUTER MANUFACTURERS
FINANCIAL DATA

| Company | Sales ($000) | Assets ($000) | Invested Capital ($000) | Employees | NET INCOME: Total ($000) | NET INCOME: As Percentage of Sales | NET INCOME: As Percentage of Invested Capital |
|---|---|---|---|---|---|---|---|
| Burroughs (149) | 751,819 | 1,115,516 | 416,949 | 52,627 | 55,199 | 7.3 | 13.2 |
| Control Data (188) | 570,766 | 1,169,466 | 657,855 | 24,000 | 53,336 | 9.3 | 8.1 |
| Digital Equipment (730) | 87,867 | 61,849 | 45,317 | 4,360 | 9,329 | 10.6 | 20.6 |
| General Electric (4) | 8,444965 | 6,007,496 | 2,539,977 | 400,000 | 278,015 | 3.3 | 10.9 |
| Honeywell (75) | 1,425,993 | 1,222,011 | 494,115 | 81,520 | 494,115 | 4.4 | 12.6 |
| IBM (5) | 7,197,295 | 7,389,958 | 5,276,991 | 258,662 | 933.873 | 13.0 | 17.7 |
| NCR (87) | 1,254,641 | 1,444,528 | 576,110 | 102,000 | 44,115 | 3.5 | 7.7 |
| RCA ( 21) | 3,187,903 | 2,634,379 | 1,023,754 | 128,000 | 151,283 | 4.7 | 14.8 |
| Sperry Rand (60) | 1,607,340 | 1,284,121 | 651,838 | 101,273 | 77,036 | 4.8 | 11.8 |
| Xerox Dat (71) | 1,482,895 | 1,555,197 | 762,381 | 54,882 | 161,360 | 10.9 | 21.2 |

Source: Fortune, "Top 500, and Top 1000 Surveys", May and June, 1970

Note: Ranking among the top 1000 firms is shown in parenthesis

TABLE XVI

Burroughs, indicated in the October 1970 announcements that its data processing division has been profitable since mid-1968 "and is continuing to grow in profitability."[327]

To compare some of these profit indicators with what little measure of expected profit performance has developed in the industry, Table XVII has been prepared from J. S. Bain's classic study of concentration, height barrier to entry and average profit rates. Caves commented on this data, that either high concentration or high barrier to entry in an industry tends to produce a high profit rate. That high rate is in turn an indication that the industry contains too few factors of production.[328]

The question of concentration has been raised in basic conditions, and the market share of each of the leading ten manufacturers in Table III. Further data from the 1967 Census of Manufacturers on concentration ranked the leading firms as follows:

Value Added by Manufacture (SIC 3573)

| | Per cent accounted for by -- | | | | |
|---|---|---|---|---|---|
| Total (million dollars) | 4 largest companies | 8 largest companies | 20 largest companies | 50 largest companies | Total firms |
| 1,926.4 | 66 | 83 | 92 | 98 | 134 |

Another common representation of concentration ratios is the Lorenz curve and its Gini coefficient. It represents

[327]Schmedel, "Burroughs New Family," p. 30.

[328]Caves, p. 108.

GENERAL STATISTICS OF PROFIT, [illegible], AND CONCENTRATION

Average Profit Rates for Industries Grouped According
Seller Concentration and Barriers to Entry

| Level of Seller Concentration * | Height of Barriers to Entry: High | Medium | Low |
|---|---|---|---|
| 1. Average profit for the years 1936-1940 | | | |
| High | 19.0 | 10.2 | 10.5 |
| Low | --- | 7.0 | 5.3 |
| 2. Average profit rates for the years 1947-1951 | | | |
| High | 19.0 | 13.4 | 15.4 |
| Low | --- | 12.5 | 10.1 |

* High concentration indicates that the largest 8 sellers during the period in question controlled 70 per cent or more of sales by the industry; low concentration indicates that the top 8 controlled less than 70 per cent.

Source: Bain, Joe S., Barriers to New Competition, Harvard University Press, 1956, Chapter 7, as published in Caves, Richard, American Industry: Structure, Conduct, Performance, Prentice-Hall, 1967, p. 108.

TABLE XVII

graphically the dispersion accounted for by any number of firms possessing a greater market share than any of the remainder; equality would be represented by the diagonal, sometimes referred to as the diagonal of equal distribution. It has acknowledged drawbacks which occur in large numbers of firms many of which possess very small percentages and yet occupy an equivalent linear ranking by this method. Figure 7 is the Lorenz Curve for the computer industry based on 1969 data of Table XII and its ten firms; the use of an eleventh category for the remainder was applied to reduce the undesirable effect of many firms. That such did not essentially alter the picture unreasonably was tested by using data for all 134 firms assigning 124 firms a 1/124 per cent of the remaining industry output value. That result is presented in Figure 8.

The measure of dispersion, the Gini coefficients, were calculated as follows:[329]

1. Sum of the areas below the Lorenz curve:

   10 firms = 1554
   134 firms = 103.96

2. Area of concentration:

   (5000 - 1554) 10 firms = 3446
   (5000-103.96) 134 firms = 4896.04

3. Gini coefficient:

$$10 \text{ firms} = \frac{3446}{5000} = .689$$

$$134 \text{ firms} = \frac{4896}{5000} = .897$$

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[329] Singer, E. M., Chapter 13; see also Scherer, p. 50-52.

COMPUTER INDUSTRY LORENZ CURVE: 10 FIRMS

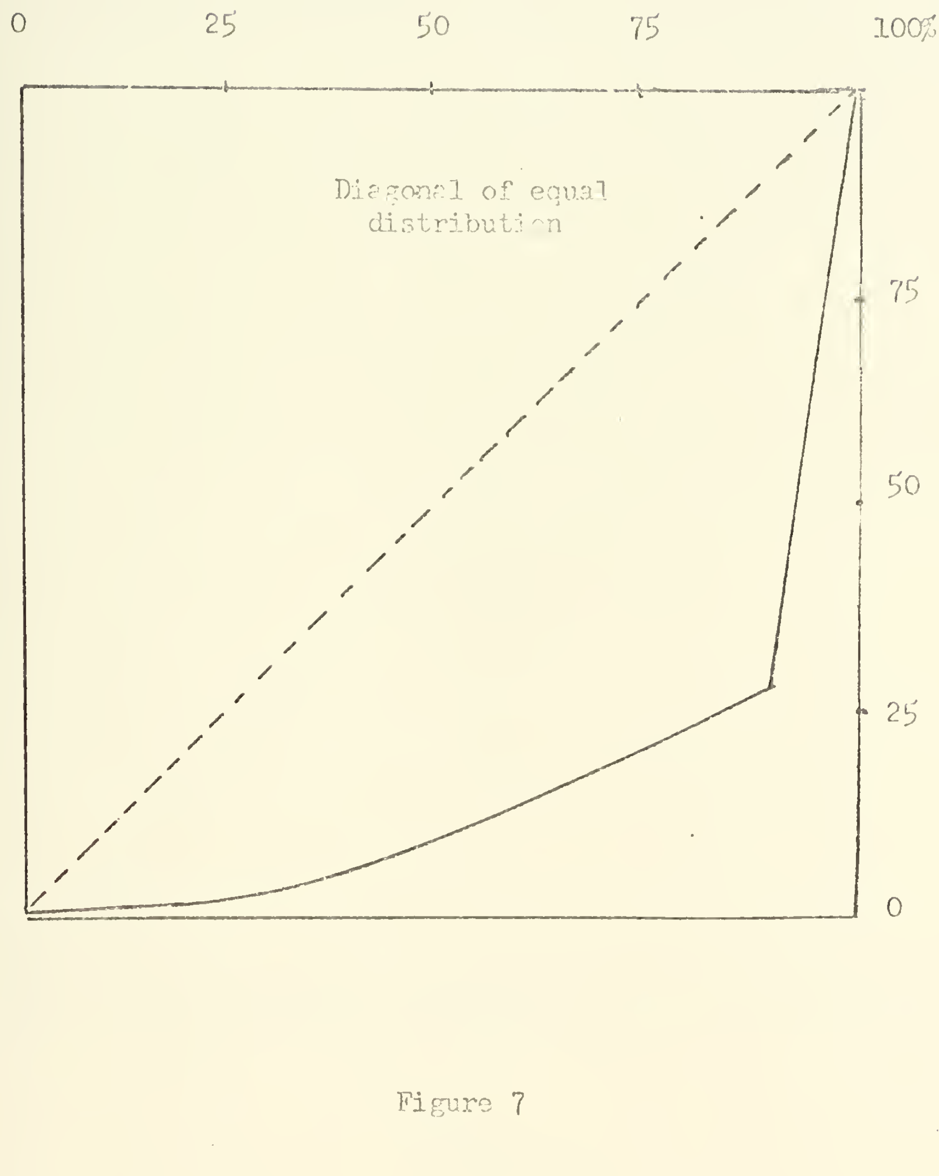


Figure 7

COMPUTER INDUSTRY LORENZ CURVE: 134 FIRMS

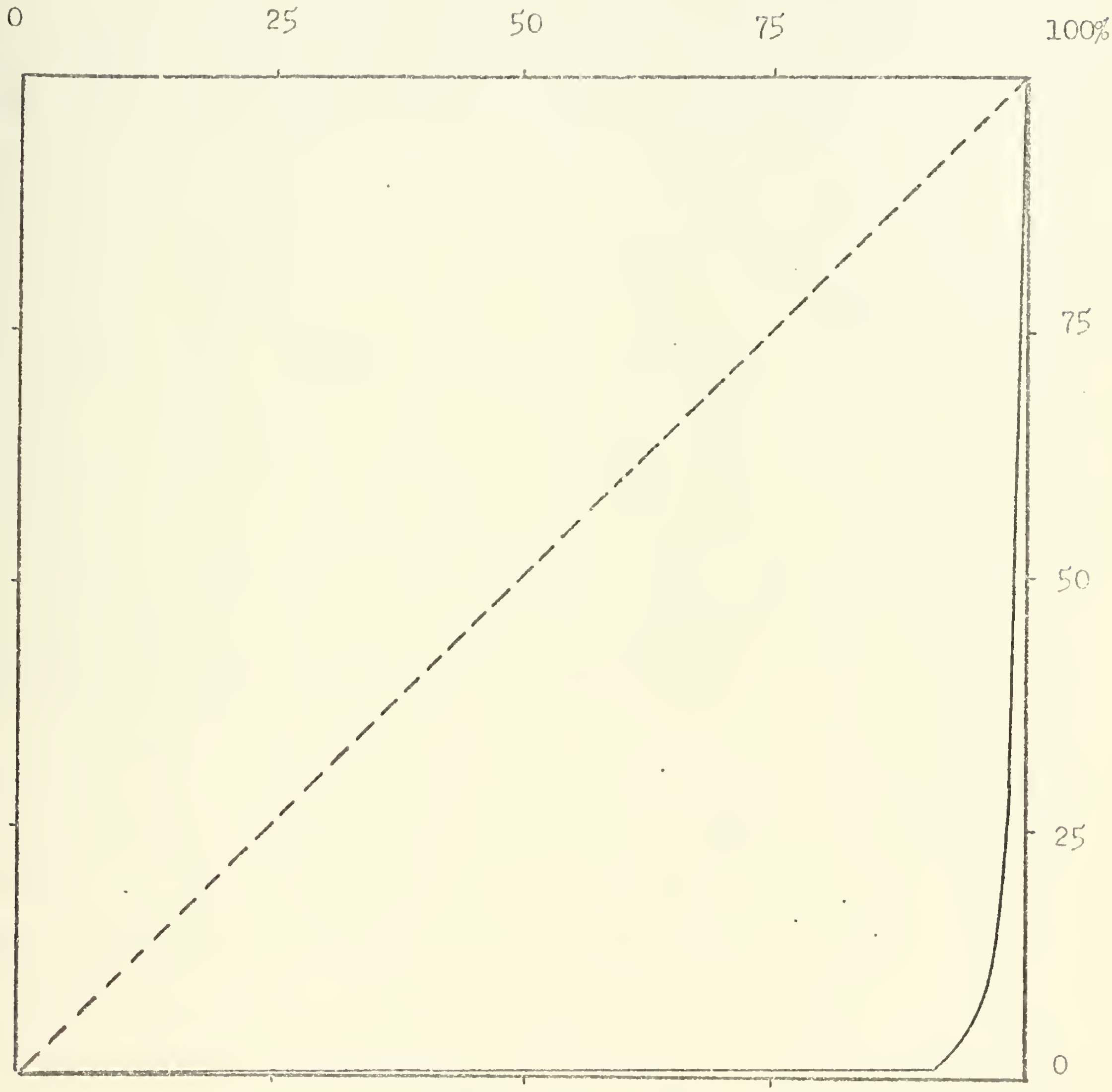


Figure 8

In addition, the Gini coefficient was calculated for installed equipment values for 1969 data, also shown in Table III. It was found to be .6924, closely approximating the shipment values.

The Herfindahl index is preferred by Scherer and correlates highly with concentration ratios from the Department of Commerce statistics, and the four-firm concentration ratio (sales to industry sales). Scherer finally notes that they all correlate well to indicate a measure of concentration. The four-firm concentration ratio for the computer industry using the 1969 shipment values and firms was found to be 0.836. If Honeywell and GE had been combined that ratio would have been 0.867. Bain's study of a different period of twenty industries resulted in a four-firm 1947 concentration ratio of .61 for a select group of concentrated industries, and .41 for all industries.

Although no reliable data could be found concerning the expenditures for advertising and promotion of computer products, it would not appear to differ abnormally from other industries which deal in industrial products.

2. <u>Progress</u>

The computer industry was found to differ in the apparent innovative trend, even among the largest firms. The rather open-entry software industry has served to keep some pressure on developmental systems. Inventiveness or innovation is not necessarily interchangeable with progress nor patents. The computer generation cycle seems to provide a research tempo requirement that even motivated the

dominant firm. While this varies with findings of Caves, Scherer, Schumpeter and Stigler, it could be explained in part by the early growth of computer technology suggested by Schwartz and Heilborn. The basic research being pursued by IBM, Burroughs, RCA, Control Data, Univac and Honeywell would indicate large firms with the capability are heavily engaged in technology which is finding its way into products, even if patents would not so indicate.

Important discoveries which were previously listed in memory technology have punctuated hardware generations. IBM held back on monolithic circuit chips at the outset of the System 360; this may be an excellent example of where the buck stops under heavy pressure of Watson's design engineer. The business manager par excellence resisted the pressure of the scientist, to meet a more probable delivery schedule. In the analysis of progress it is acknowledged that had IBM elected the monolithic circuits and failed, no advance would have reached the market place that April 7, 1964.

3. Equity

The distribution of income because of the computer industry's high salary levels and impetus and reward system to scientific personnel cannot be considered out of balance with the rest of industry. The total industry employment is very small leading to income concentration as a promised reward for skilled performance. The umbrella effect for the remaining firms could be viewed as equitable among various firms; yet the reports of the past ten years indicate inflated salary levels of relatively short duration could be an example of personnel waste.

4. Full Employment

No true statistics are available, yet the computer industry is said to have reasonably good resistance to economic downturn, largely because of the personnel policies of the dominant firm. RCA's recent announcement of hardware indicated an expansion of 2000 employees in Marlboro, Massachusetts, at a time when unemployment in U. S. industries recently surpassed 5.8% (December 4, 1970). The Department of Commerce, Annual Survey of 1968 compared total employee figures which revealed approximately an 8% increase in employment in the computer industry. In short, to date the performance of the computer industry has been to maintain more stable employment than other U. S. firms in general.

A summary of the market structure, conduct, and performance confirm that good ideas are marketable commodities as envisioned in the minds of the framers of the U. S. Constitution who provided for the protection of inventions in the U. S. patent system. Computer manufacturers have evolved in an industry that began as a scientific experiment and today has provided equipment to more than 50,000 organizations (per Withington) to assist in the production of America's goods and services. The standard of living improvement has continued to rise as a measure of all industry's contributions. The computer is to be found in the improvement of the use of scarce resources, and to speed the progress of other scientific and business research.

Business together with the services' industry have developed applications which are more effective than earlier

attempts of the 1960's. State and local governments have also found diverse computer applications to ease growing urban and environment control problems. The performance of the industry is not just the performance of the leader: IBM. Many firms have participated in the technological advances. No single foreign competition has been able to yet master the technology capital and marketing capability of the American firms, although some will surely attempt the duplication of technology.

Thus there is strong indication that the market structure inherently provides an opportunity for future misallocation of resources. High entry requirements and very high concentration are indicated, but capital intensity appears to be essential to the effective early technology and hardware development.

## IV. GOVERNMENT REGULATION

The previous section examined supply and demand, the structure, conduct, and performance of the computer industry, as they are determined by the natural producer/consumer interaction known as the market mechanism. As long as this market mechanism functions smoothly and serves the best interests of the consumer, it acts as the sole determinant of the characteristics of the industry. However, when the market processes go astray, some sort of governmental regulatory policy is generally applied. Governmental intervention can take many forms, ranging from moral suasion and the glare of publicity to public ownership. The main weapon used, in attempting to harmonize the profit-seeking motives of private companies with the public interest, has been the enforcement of antitrust policy.

Antitrust policy in the U. S. has its basis in three significant statutes - the Sherman Act of 1890, the Clayton Act of 1914, and the Federal Trade Commission Act of 1914. In very general terms, the Sherman Act outlawed acts of monopolizing, the Clayton Act prohibited acts tending to result in the growth of a monopoly, and the FTC Act banned unfair competition.

Specifically, Section 1 of the Sherman Act prohibits contracts, combinations, and conspiracies in restraint of trade or commerce. Section 2 prohibits monopolization,

attempts to monopolize, and combinations or conspiracies to monopolize trade or commerce.[330]

The Clayton Act attempted to close the loopholes in the Sherman Act, and terminate the growth of monopoly in its earliest stages. The following practices were declared unlawful when the effect was to substantially lesson competition or create tendencies toward monopolies: (1) price discrimination, (2) tying clauses and exclusive dealing arrangements, (3) acquisition of stock in competing companies, and (4) interlocking directorates among competing firms.[331]

The Federal Trade Commission Act established five full time commissioners with quasi-judicial power, and among other things, outlawed unfair methods of competition. However, it left to the Commission the problem of defining what were "unfair methods."[332]

Although these three acts form the nucleus of U. S. antitrust policy, the implementation of the law through the years has been greatly affected by the interpretation of the courts. Decisions have tended to indicate that market dominance itself is grounds for antitrust action. "Restraint of trade" has been interpreted as "unreasonable" restraint of trade, with the term "unreasonable" not defined. Monopoly power has been adjudged to be "power or ability to fix prices in a market, or exclude competition from ...," but no simple definition of "market" and no means of measuring monopoly power (percentage of market control) have been provided.[333]

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[330]Scherer, p. 424-425.

[331]Ibid.

[332]Ibid.

The actions taken against firms found guilty of antitrust violations take many forms. The intent of the actions is either to inhibit or prohibit certain undesirable business conduct, or to channel and shape the market structure along competitive lines so that desirable conduct and performance will emerge automatically. Since there are no standard penalties in antitrust cases, firms can never be sure of what action will be taken if they pursue certain (illegal) activities.

## A. PREVIOUS ANTITRUST ACTIONS

As has been pointed out repeatedly in the study thus far, IBM was the dominant firm first in the tabulating machine industry and then in the computer manufacturing industry. Not surprisingly, the Justice Department, as well as competing manufacturers, have shown a continuing interest in IBM's business practices and its share of the market.

### 1. The 1936 Conviction

In 1932, the United States filed an antitrust suit against IBM and Remington Rand, Inc., charging that they had unreasonably restrained and monopolized interstate trade and commerce in violation of the Sherman and Clayton Acts.

The federal government charged that: (1) IBM and Remington Rand had entered into an agreement to sell punched cards only to lessees of their card handling equipment, and not to solicit business for cards from any user of the other party's machines, (2) both parties would not sell their machines, but would only lease them, and (3) the lease contract

required that the punched cards used in the machines be purchased exclusively from the lessor (tying clause), or that additional rental be paid for the machines.[334] These acts constituted restraint of trade, and had resulted in the formation of a monopoly. IBM and Remington Rand owned substantially all of the card processing machines used in the United States. IBM alone had under lease 85.7% of the tab machines, 86.1% of the sorting machines and 81.6% of all punches.

The case came to trial in 1934. By then, the IBM/Remington Rand agreement had been terminated, and that charge was therefore cancelled by stipulation. Remington Rand chose not to enter the proceedings and agreed to consent to the finding against IBM. At the trial, IBM argued that its insistence on the use of IBM cards constituted a reasonable control, that only IBM could manufacture cards meeting specifications, and that defects in cards would lead to bad performance, increased maintenance and loss of customer "goodwill".[335] In previous cases involving "tying clauses" of the Clayton Act, the court had been willing to consider such extenuating circumstances.[336] The issue in this instance, however, was whether competition had been substantially lessoned. The facts indicated that except for IBM and Remington Rand, where the situation had been mutually

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[334] Rodgers, p. 129-130; and Neale, A. D., The Antitrust Laws of the United States, Cambridge at the University Press, 1960, p. 287.

[335] Rodgers, p. 129-130; and Neale, p. 287-288.

[336] Scherer, p. 506.

stabilized, there was none (competition). The court returned a finding of guilty.[337]

In the appeal before the Supreme Court in 1936, the decision was affirmed. IBM argued that since the condition contained in the leases did not extend beyond the monopoly acquired by patents, the leases were lawful. The court pointed out that the Clayton Act made tying clauses unlawful whether the machine involved was patented or unpatented. The Act did not purport to deny patent protection, but it did prohibit the benefit of a tying condition.[338] Regarding the contention that tying clauses were necessary to protect "goodwill", the court noted that others, namely the federal government, were capable of manufacturing suitable cards at substantially less cost than the price charges by IBM.[339]

IBM was required to discontinue the required use of its own cards, but was allowed to require the cards to meet minimum standards. It was further permitted to continue its lease-only policy.[340]

The outcome proved to be a hollow victory for the Justice Department. IBM prescribed highly stringent standards for cards used in its machines, and since it held the patents on the superior automatic rotary card press, no other company could produce cards to meet its specifications.[341]

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[337] Rodgers, p. 129-130.

[338] Handler, M., Cases and Other Materials on Trade Regulation, The Foundation Press, 1960, p. 314-315.

[339] Neale, p. 288.

[340] Sharpe, p. 248.

[341] Ibid.

2. The 1956 Decree

In 1947, the Justice Department began a new investigation, this time in an effort to eliminate the lease-only policy, and make the card press patents available to other companies.[342] In 1950, after three years of investigation, the Justice officials made it known they would be willing to accept an IBM agreement to license its patents for reasonable charges. IBM refused and the investigation continued.[343]

The civil antitrust suit was filed by the Justice Department on January 21, 1952, charging that IBM had violated Sections 1 and 2 of the Sherman Act by attempting to monopolize and monopolizing interstate trade and commerce in the tabulating industry.[344] The complaint alleged that IBM was the largest tabulating machine manufacturer in the world, that it owned more than 90% of all the tabulating machines in the U. S., and that it manufactured and sold about 90% of all the tabulating cards sold in the U. S.[345] The government charged that the heart of IBM's domination was its patent pool of several thousand essential patents in the tabulating machine and related fields. Further,

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[342] Rodgers, p. 211-212.

[343] Belden, p. 298.

[344] U.S. v. International Business Machine Corporation, Civil Action No. 69 CIV. 200 filed January 14, 1969, in the U. S. District Court for the Southern District of New York, p. 5. Hereafter cited as "U.S. v. IBM, 1969".

IBM obliged the lessee of its equipment to take a package including instruction, repair, and service by IBM.[346]

Even after filing suit, a continuing attempt was made to settle out of court through the formal process of a consent decree. A consent decree leaves unresolved the question of guilt or innocence, but its terms are binding once approved by a federal court. Although IBM was reportedly spending $3 million per year in preparation of its defense, it opposed the out-of-court proceeding.[347]

A strikingly similar case was being fought in the courts, at this same time, by the United Shoe Company. In 1953, a Massachusetts court found against United Shoe, and required it to sell (vice lease only) its equipment, offer only short term rentals, and license all its patents at reasonable royalties. The decision was upheld by the Supreme Court in 1954.[348]

Early in 1956, Thomas Watson Jr., president of IBM, signed the consent decree. Terms of the decree required IBM to sell its tabulating machines at reasonable prices not substantially more advantageous to IBM than lease charges; provide maintenance and repairs at reasonable and non-discriminatory prices; and sell, at reasonable

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[345] Ibid.

[346] Rodgers, W. D., "Is It Trust Busting or Window Dressing?" The Reporter, 1 November 1956. Rodgers, W. D. is not cited hereafter. Any reference to "Rodgers" implies "Rodgers, W. H."

[347] Belden, p. 304.

[348] Sharpe, p. 249.

prices, up to thirty rotary presses each year from 1956 to 1961. IBM was still permitted to require the use of cards meeting certain standards, but the forced sale of its card presses would enable other companies to meet the specifications. Additionally, the decree required IBM to set up its Service Bureau Corporation as a separate subsidiary. The S.B.C. operated some 150 centers that did computing service on a fee basis. Finally, IBM was required to prove to the courts that competitive conditions existed in the tabulating card market, or divest itself of all manufacturing capability in excess of 50% of the U. S. total before 1962.[349]

In most respects, the outcome was considered successful. The terms of the decree did open the manufacture of punched cards to the competition, and allowed other companies to get started in the tabulating card field. By mid-1960, IBM no longer held a monopoly in the manufacture of tabulating cards.[350] Unfortunately, certain weaknesses were inherent in the mechanism of the consent decree. The decree was not specific as to what constituted reasonable prices. It gave IBM the chance to be evasive, and if Justice officials determined that the coporation was not living up to the terms of the decree, their only recourse

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[349] Ibid., p. 249-251.

[350] Ibid., p. 251; and "The Impact of Two Historic Antitrust Actions," Business Week, 4 February 1956, p. 56.

would be to institute court proceedings. These same weaknesses exist in almost any consent decree, and accordingly, competitors are often disappointed to see potentially spectacular actions "settled not with a bang, but a whimper."[351]

B. CURRENT LITIGATION

Although some persons may consider that the federal government has been somewhat ineffective in controlling monopoly since the Justice Department has failed to win many court decisions over IBM, the consent decree of 1956 and the fear of antitrust action since that year have significantly influenced IBM's moves in several areas.

Over the past several years, IBM has very carefully filled some corporate executive positions with formidable legal opponents for the federal government. In 1965, IBM hired Burke Marshall, former U. S. Attorney General, as its general counsel. In 1968, Nicholas de B. Katzenbach, former U. S. Attorney General and Undersecretary of State, was employed as company lawyer with the title of Vice President. Marshall is still with the company as a Corporation Vice President.[352] Finally in 1969, Cyrus Vance, direct from the Paris peace talks and formerly Deputy Secretary of Defense, joined Katzenbach's staff.[353]

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[351]Scherer, p. 464.

[352]Rodgers, p. 263.

[353]Wareham, p. 33-34.

In mid-1968, the threat of Justice's action caused IBM to transfer the marketing of its time-sharing subscriber services from its Data Processing Division to its wholly owned subsidiary, the Service Bureau Corporation. Competitors had cried "unfair competition," since under the terms of the consent decree, IBM had agreed to conduct its service operation under a separate company that did not use the IBM name.[354]

Later, in October, IBM backed down from some proposed increased charges for equipment maintenance. Complaints had come from the computer leasing firms, who would have been most affected by the increased prices.[355]

In a retrospective analysis of the 1956 decree, it is interesting to note that although some of the terms applied permanently, the first ten years were apparently considered the most crucial. The terms give a distinct impression that the government believed that after a decade the matter should be re-examined. Whether or not it was their original intent, the Department of Justice did begin a new probe of IBM practices in January 1967.[356]

1. Control Data Suit

Some of IBM's competitors could not wait any longer for Justice to act, or perhaps were not at all sure that

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[354] Drattell, Alan, "... and Now a Word from No. 1," Business Automation, January 1969, p. 38.

[355] Ibid.

[356] Sharpe, p. 251-252.

Justice would act, and therefore, on December 11, 1968, Control Data Corporation filed suit against IBM, charging violation of the Sherman Act. Control Data's action was merely the first in a series of litigations against IBM, as 1969 became known in the industry as the year of the lawsuit.

Four years earlier, when Control Data had introduced its models 6600 and 6800 computers, the largest machines of their type in the world, IBM retaliated with the announcement of its own super-computer, the 360/91. (Many of CDC's prospective customers signed up for the series 90, or at least postponed making a decision on the 6600.) When the 360/91 was slow in production, failed to meet its announced specifications, and was cancelled after only a few were delivered, Control Data's president, William Norris, suspected that IBM had marketed a phantom computer to eliminate the competition.[357]

In December of 1968, Control Data announced their newest and largest super-computer, the 7600. Obviously not wanting a repetition of the battle with the 360/91, Norris charged IBM with monopolistic practices, and asked the government for treble damages, injuctive relief, and possible dissolution or divestiture.[358]

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[357] "Tackling," p. 77.

[358] Control Data Corporation v. International Business Machines Corporation, a Civil Action filed December 11, 1968, in the U. S. District court of the United States for the District of Minnesota, Third Division, p. 11. Hereafter cited as "CDC v. IBM, 1968".

The complaint charged IBM with 37 violations of the Sherman Act including discriminatory discounts, free technical services for favored customers, reciprocal buying power, intimidating customers' procurement personnel, direct entry into the time-sharing service business, false disparagement of competitors, and "misrepresenting the status and performance" of its own prematurely announced models - an obvious reference to the 360/91.

IBM promised to "vigorously defend" itself against the charges, pointing out that the industry, contrary to the allegations, was one of the most fiercely competitive in the nation and included some of the country's most powerful companies. (In 1967, the $5.9 billion market included Sperry Rand with 5.8%, Honeywell with 5.4%, General Electric with 4.1%, Control Data with 3.4%, RCA with 3.0%, NCR with 2.4%, and Burroughs with 1.8%. IBM held the lead with 72.9%.)[359] IBM further noted that Control Data was a striking illustration of an IBM competitor that had experienced phenomenal success, In less than eleven years, Control Data's assets and revenues had grown to $465 million and $387 million respectively.[360]

Although few people anticipated that the Control Data suit would result in the dissolution of IBM, they rightly expected that it might prevent premature announcements of overstated capabilities.[361]

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[359] "Basic Analysis," p. 11, 13.

[360] "Tackling," p. 78.

[361] Ibid.

2. <u>Suit by Data Processing Financial & General Corporation</u>

On January 3, 1969, Data Processing Financial & General, a New York computer leasing company, filed a 39 page complaint against IBM in the federal district court of the Southern District of New York, alleging violations of antitrust laws, the consent decree of 1956, and state unfair competition laws. DPF&G claimed that bundling (i.e., combining software, maintenance, education, and engineering services under a single unseparable price for equipment), along with discriminatory maintenance policies, and intimidation of users planning to acquire competitive peripheral equipment had restrained competition. It also charged that an increasing gap between purchase and rental prices on new machines, and higher maintenance prices on purchased systems, were violations of the consent decree which required sale as well as rental of IBM equipment, at a reasonably comparable pricing relationship.[362]

The complaint asked for treble damages of more than a billion dollars, and more significantly demanded a divestiture from IBM's manufacturing activity of its software, maintenance, and leasing operations. DPF&G hoped to split IBM into four separate corporations, only one of which could use the name IBM.[363]

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[362] Pantages, Angeline, "Sweet Sue: Another Firm Takes a Swing at IBM and Justice May Leave Neutral Corner," <u>Datamation</u>, February 1969, p. 101. Hereafter cited as "Sweet Sue."

[363] <u>Ibid</u>.

One effect of the suit by DPF&G, as with the previous charges by Control Data, was the required opening of IBM files to the plaintiffs. It was considered likely that all IBM documents and accounting records would go into a "national depository" to which all parties to the antitrust proceedings would have access.[364]

In August of 1970, DPF&G dropped their suit and settled out of court with IBM. The settlement, apparently forced by financial strain within DPF&G, provided for the company to be reimbursed by IBM for the legal costs incurred in the lawsuit. In addition, IBM agreed to refinance DPF&G's $42 million debt to IBM by extending the payment period at the existing interest rate. The debt was incurred in the purchase of IBM computers. DPF&G appeared relieved over the elimination of the burden of the suit.[365]

3. The Justice Department Suit

On January 17, in the waning hours of the Johnson administration, Attorney General Ramsey Clark and the Department of Justice filed a major antitrust action against IBM in the U. S. District Court of the Southern District of New York. Although only twelve pages, it covered the major complaints contained in the previous suits by Control Data and DPF&G, but limited itself to monopoly charges with no reference to improper conduct.[366]

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[364] Ibid., p. 102.

[365] "Data Processing, IBM End Antitrust Dispute, Settle Out of Court," Wall Street Journal, 1 September 1970, p. 4.

[366] U.S. v. IBM, 1969, p. 7-9.

Specifically, the claim spelled out four ways in which IBM allegedly inhibited the competition in violation of Section 2 of the Sherman Act: (1) its single pricing policy, (2) announcing new models before they were ready, (3) marketing models with unusually low profit expectations, and (4) granting discriminatory allowances for universities.[367] The government "prayed" that IBM be required to refrain from these acts leading toward monopoly and be subject to such divorcement, divestiture, and reorganization as the court may consider necessary to restore competitive conditions to the industry.[368]

Reactions to the Justice Department suit were somewhat bewildering and not completely anticipated. IBM had already announced that it was going to make an announcement in July about pricing, but it was still the responsibility of the courts or a decree to permanently seal the IBM unbundled prices. Surprisingly, IBM competitors began to have second thoughts about the possible effects of the federal action.

Since the Sherman Act suit was a structural suit, it was bound to change the organization of the industry, determine IBM's share in it, and predestine which competitors would die or grow. Would four separate IBM's grow to evenlop an even larger per cent of the market?

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[367]"Yapping," p. 67.

[368]U.S. v. IBM, 1969, p. 10-11.

Without the special allowances, many universities would not have been able to afford the equipment and research which helped to advance the technology. If IBM were enjoined from announcing new computers well in advance of delivery, competitors who followed the lead of IBM in developing compatible computers and peripherals would be the ones to suffer most from the shortened lead time.[369]

Some experts feel that Justice will not try to win the case but will settle for another consent decree, since a court victory would open up IBM to treble damage claims from everyone, which would be detrimental to consumers and competitors alike.[370] (Consent decrees, unlike court decisions, cannot be used as evidence in subsequent proceedings.)

Finally, IBM's adroit shifting of its engineering and marketing efforts from tab machines to computers following the consent decree of 1956, resulted in the terms of the decree being somewhat less than effective with respect to the new market. Similarly, since the current Justice action will likely take years to prosecute, the court faces a major problem of finding a solution which will be relevant to the rapidly changing industry in the future.[371]

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[369] Pantages, Angeline, "Justice vs. IBM: Strike Three and You're Ahead of the Game," Datamation, March 1969, p. 99-101.

[370] Pantages, "Sweet Sue," p. 101-102.

[371] "IBM Girds for Battle," Business Week, 25 January 1969, p. 38.

4. Action by Applied Data Research and Programmatics

In April of 1969, Applied Data Research, Inc., a Princeton, New Jersey software firm, filed the fourth in what appeared to be a continuing series of suits against IBM. Filed in the Southern District Court of New York, the complaint alleged violations of both the Sherman and Clayton Acts, the consent decree of 1956, and the unfair competition laws. Among the several allegations, ADR's parochial interest in software patents also emerged. The charges alleged patent misuse, in that IBM had threatened to enforce its patents against the software companies, and fraud against the U. S. Patent Office, in that IBM had applied for patents on software disguised as hardware.[372]

ADR asked the court to award treble damages amounting to over $900 million, and to have IBM divest itself of software manufacturing, price its software separately in the meantime, and rebate to customers the price of software acquired free with the IBM equipment. ADR requested an amount of $3.57 billion be set aside by IBM for these rebates.[373]

The following month, Programmatics, Inc., a Los Angeles software firm, tried a different tact by seeking an injunction to prevent IBM from distributing without

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[372] Pantages, "Thin Defense," p. 121.

[373] "IBM Hit with Fourth Civil Antitrust Suit as a Software Concern Alleges Monopoly," Wall Street Journal, 23 April 1969, p. 5.

charge a software package with which Programmatic's own program was incompatible. The company claimed that IBM developed the new program to shut it out of the market.[374]

The injunction was denied, Programmatics appealed, and its case was scheduled to be heard on a consolidated basis with the cases of the other three commercial firms. Later, however, Programmatics was acquired by Applied Data Research, and in mid-1970, both companies with severe financial difficulties agreed to dismiss their actions against IBM. In return, IBM paid about $1.4 million to ADR "for certain costs incurred in connection with the matters at issue."[375]

5. Unbundling and More Lawsuits

In December of 1968, probably in reaction to the new investigation begun by the Justice Department and the threat of antitrust suit, IBM announced that by July of the following year, it would make a new policy statement on pricing. True to its word, on June 23, IBM told the industry that effective January 1970, it would unbundle the pricing of hardware, software, maintenance, and engineering. The details of this move, and the reactions of other manufacturers, were discussed earlier in section III of the study. The full impact of the maneuver on the industry remains to be seen.[376]

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[374] "Applied Data, Unit and IBM Settle Antitrust Suits," The Wall Street Journal, 21 August 1970, p. 2.

[375] Ibid.

[376] Dahl, Aubrey, "1969: An Overview of the News," Datamation, January 1970, p. 91.

The unbundling announcement kicked off two additional suits against IBM. Motor Replacements, Inc., sued for $5 billion charging that because of unbundling IBM would no longer provide without charge the contracted "lifetime programming services." The action was a "class suit" which would entitle all other IBM customers to collect similar damages. Later, another suit was filed by Greyhound Computer Corporation charging that the three per cent equipment price increase resulting from unbundling would prevent it from conducting profitable operations in the computer leasing market.[377]

The battles spilled over into 1970, when the giant of the copying machine industry, Xerox Corporation, filed a patent infringement suit in Federal district court against IBM upon the announcement of its first office copier. IBM quite naturally responded that its new machine did not involve any of Xerox's patents or confidential information.[378]

As recently as October of 1970, the actions continued to develop, as VIP Systems, a Washington-based firm engaged in data processing and computer time-sharing filed suit against IBM for antitrust violations. VIP is seeking treble damages of $5 million and injunctive restraint.[379]

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[377] Ibid., p. 89.

[378] "IBM Introduces Copier, and Xerox Files Patent Suit," The Wall Street Journal, 22 April 1970, p. 4.

[379] "VIP Names IBM in Antitrust Case," The San Francisco Chronicle, 21 October 1970, p. 59.

Still pending are the major litigations of Control Data and the Justice Department. Both are immersed in exhaustive pretrial proceedings.

6. The Federal Communications Commission

As though the everpresent threat of antitrust action by the Justice Department were not enough, another federal agency has considered the necessity of regulating the computer industry. In November of 1966, the Federal Communications Commission began an investigation to determine whether computer time-sharing devices utilizing telephone lines should come under federal regulation and be subject to FCC established rates.[380]

In April of 1970, the FCC ruled that the industry need not be subjected to government regulation for the time being. An interesting aspect of the announcement was the justification for the ruling. The FCC decided that the computer industry should be exempt because their activities currently were competitive. The decision would be reviewed if significant structural changes occurred in the industry.[381]

## C. THE EFFECTIVENESS OF ANTITRUST

Even a detailed analysis of historical antitrust actions fails to provide a clear answer as to what extent government regulations has affected the structure and

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[380] "IBM Comes Under Antitrusters' Gaze," Business Week, 14 January 1967, p. 34.

[381] "FCC Disclaims Need to Regulate Data Processing," The Wall Street Journal, 3 April 1970, p. 5.

conduct of the computer industry. It is difficult to determine whether the natural market mechanism or public policy has been the more influencial force. Both have played significant roles in shaping the industry as it exists today.

Obviously the success of the Department of Justice in the courts has been limited, but the omnipresent threat of litigation by the federal government has certainly been effective in motivating the behavior of the dominant firm in the industry.

IBM watchers have observed even a slight reduction in the share of the market held by the giant. Although, IBM competitors may have increased their efficiency at capturing a larger percentage of the trade, it is just as probable that IBM is softening its effort in order to slide just under that precedent-established critical level of 70%.

Further, IBM's top management has adopted a somewhat protective attitude toward their competition. Although the level of IBM profits would easily permit some significant price cuts, such a move would undoubtedly push some of the smaller companies out of the profit-making range entirely. IBM, sensitive to the close scrutiny given it by Justice, prefers to keep prices high in order not to drive its competitors out of the industry.

Although IBM emphasized that unbundling had been in its plans for months prior to the siege of antitrust suits which began to bombard it in 1969, the separate

pricing policy unquestionably was precipitated by the threat and anticipation of monopolization litigation.

Millions of dollars and thousands of man hours have been spent by IBM in preparation of a "vigorous defense." These were resources that might otherwise have been applied to the business of manufacturing computers. Millions of dollars have been paid to competing companies in out-of-court settlements. Additionally, as a result of the multitude of litigation initiated in 1969, more of the private secrets and privileged data about IBM will not be known than ever before, as the courts made available to plaintiffs all IBM accounting records and files.

Although the threat of federal action has measurably influenced the industry, the successful litigations have had a somewhat less significant effect. As was mentioned earlier, the problem of court proceedings, or even consent decrees, in a dynamic industry is that the decisions and rulings are often outstripped by technology. The issues of the 1930's and 1950's involving tabulating machines and punched cards became relatively insignificant in the industry of computer manufacturing. Similarly, the issues under adjudication today may be totally irrelevant in future years as the emphasis shifts to the areas of time-sharing, service bureaus, and possibly computer utilities.

Finally, most competitor suits and all complaints by the Justice Department routinely "pray" for divorce,

divestiture and dissolution of the goliath, IBM. Should this goal ever be accomplished, and IBM be broken up into separate companies, the probable results would be contrary to the wishes of any other member of the industry. Many experts suggest that, just as did "Rockefeller's oil monopoly, the fragments can be counted on to grow in size and market dominance separately, perhaps to greater range and size that is possible in unity."[382]

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[382]Rodgers, p. 302.

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| 6. | LCDR Richard Calude Hogan, USN<br>Navy Ships Parts Control Center (710)<br>Mechanicsburg, Pennsylvania 17055 | 1 |
| 7. | H. A. Cardinali<br>SMC #2314<br>Naval Postgraduate School<br>Monterey, California 93940 | 1 |
| 8. | Lt. Col. R. P. Chaney, USMC<br>17 Berwick Drive, Rte #2<br>Carmel, California 93921 | 1 |
| 9. | LT T. T. Czech, USN<br>14202 Tracy Avenue<br>Riverdale, Illinois 60627 | 1 |
| 10. | P. E. Bishop<br>SMC #2898<br>Naval Postgraduate School<br>Monterey, California 93940 | 1 |

11. LCDR K. L. Carlsen, USN 1
VAQ-129
Naval Air Station
Whidbey Island
Oak Harbor, Washington 98277

12. LT Paul R. Fletcher, USN 1
5329 Allendale Road
Washington, D. C. 20016

13. LCDR L. L. Haase, SC, USN 1
Officer in Charge
FMSO Branch
U. S. Navy
Bayonne, New Jersey 07940

14. P. L. Casaquite 1
Apt. #16, Redemptorist Road
Baclaran Paranaque
Rizal, Philippines

15. LCDR W. E. Rickman, USN 1
SSBN-642
FPO New York 09501

16. LCDR R. Leisenring, SC, USN 1
8632 Maryford Drive
San Diego, California 92119

17. LCDR R. W. Groom, SC, USN 1
521 Hibiscus Court
Chula Vista, California 92011

18. CDR J. F. Le Blanc 1
Defense General Supply Center
DGSC-XO
Richmond, Virginia 23219

19. LT J. E. Maitland, USN 1
C/O C. R. Green
10427 Ditson Street
Sunland, California 91040

20. LCDR Michael J. Madden, USN 1
RVAH 3
Naval Air Station
Albany, Georgia 31703

21. LCDR John Pfeiffer, USN 1
9-18 124 Street
College Point, New York 11356

22. LT J. P. Reason, USN 1
USS Enterprise (CVAN-65)
FPO San Francisco 96601

23. LCDR W. L. Powell, USN 1
3286 Michael Drive
Marina, California 93933

24. LT Richard Michael Smith, SC, USN 1
Aviation Supply Office
700 Robbins Avenue
Philadelphia, Pennsylvania 19020

25. Cemal Sermiyasoglu 1
HACI Halit Bey Arsa Sokak
No. 15
Besiktas-Istanbul
Turkey

26. LCDR J. P. Weikert, USN 1
USS Seahorse, SSN 669
FPO New York 09501

27. LCDR P. H. Schultz 1
General Delivery
Culver City, California 90230

28. LCDR David Vincent, USN 1
1284 Leahy Road
Monterey, California 93940

29. R. M. Roderick 1
SMC #2635
Naval Postgraduate School
Monterey, California 93940

30. CDR R. E. Saunders, USN 1
VP-22
FPO San Francisco 96601

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Thomas Hadley Billings
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13. ABSTRACT

A study of the origins and evolution of the computer manufacturing industry in the United States, with emphasis on the economic importance of its present structure and conduct. The examination of supply and demand as determinants of the market mechanism is presented in a classic outline of current economic form for the market structure, conduct and performance of basic industries. The analysis of demand utilizes the first published government material on the computer industry. Derivation of Lorenz curves for this new industry and its concentration represent the first so produced. The synthesis of the manufacturers' performance is developed from the structure and conduct. That performance is separately examined in reference to public policy, with emphasis on current legal actions and anti-trust suits.

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